DISEASES OF GREENHOUSE CROPS

AND THEIR CONTROL

J. J. TAUBENHAUS, Ph.D.

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DISEASES
OF GREENHOUSE CROPS
AND THEIR CONTROL

BY

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THIS BOOK IS AFFECTIONATELY
DEDICATED TO MY WIFE

INTRODUCTION

The art of forcing vegetables and flowers is not a new one; however, its economic aspect is of modern origin. The Thirteenth Census of the United States estimates that the total area of land under glass in 1909 was 114,655,000 square feet, of which 105,166,000 square feet were in greenhouses and 9,490,000 feet were covered by sashes and frames. About 99% of the value of the plants and flowers in 1909 was produced in 7,444 establishments, the average value of each of these establishments being $4,630.00. As is natural to expect, these establishments were located near large cities. The leading states in value of forced flowers and plants were New York with $5,110,000; Pennsylvania with $3,761,000; Illinois with $3,681,000; New Jersey with $2,839,000; Massachusetts with $2,432,000; Ohio with $2,357,000; California with $1,374,000; Indiana with $1,202,000; Michigan with $1,132,000; and Connecticut with $1,042,000. States with less than a million are not here recorded. The total value of forced plants and flowers as estimated for 1909 was $24,930,000.

There are as yet no available figures of the area and the money value of the greenhouse industry. It is, however, reasonable to suppose that the num-

ber of establishments and their money value have lately increased by at least fifty per cent. This, therefore, represents a vast sum of money and an important industry of the United States which cannot be ignored.

Plants under greenhouse culture are far from being subjected to normal conditions. The expression "tender as a hothouse plant" well expresses the truth. Because of this fact greenhouse plants are naturally more susceptible to diseases indoors than similar plants grown in the open. This at once emphasizes the importance of studying the diseases of greenhouse crops with a view to furnishing the growers such information as may help them to reduce important plant diseases and thereby increase their profits. We have as yet no available figures as to the money losses from diseases of greenhouse crops. A conservative estimate, however, may place these losses at about thirty per cent.

The literature on diseases of greenhouse crops in the United States is rather fragmentary and scattered. The American Plant Pathologists have been too busy in devoting much time to the investigations of the diseases of cereals, fruit and truck crops. Considering that plant pathology is only a new science, the diseases of the greenhouse crops had of necessity to be neglected. It is, therefore, the aim and purpose of the present volume to bring together available information on the subject and to place it at the disposal of the greenhouse men. The author realizes too well the incompleteness of this work;

however, it is felt that no apologies are due and it is hoped that it will meet an important demand for information, and stimulate further research in this line. The book is intended as a guide to practical growers, teachers, students and investigators in plant pathology. It is taken for granted that the practical man who uses this volume will study it with a view to gathering information to serve him as a guide, as no definite hard rules are here laid down which could apply to the problems of each individual case. It is only by combining the information with good common sense that the best results are to be obtained. Constructive criticism is solicited and helpful suggestions will be gratefully received.

Acknowledgments are here due to Dr. and Mrs. D. de Sola Pool of New York City; Dr. I. Adlerblum, Statistician of the Metropolitan Life Insurance Company, New York City; Professor R. B. Brackett, Professor of English of the Texas A. and M. College; Professor S. C. Hoyle, Editor Extension Service Publication, Texas A. and M. College, for helpful criticisms and for reading the manuscript and proofs; to Professor F. B. Paddock, Entomologist, Texas A. and M. Agricultural Experiment Station, for reading the proofs; Miss Florence Buckman of the Plant Pathology Division, Texas Experiment Station for assistance in preparing the glossary and the index.

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J. J. TAUBENHAUS

College Station, Texas
May 1, 1919

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CHAPTER I

THE HEALTHY SOIL

An intelligent understanding of the soil is of paramount importance to the success of the greenhouse. There are three important points that we must consider in the study of a healthy soil. They are: (1) texture, (2) fertilizers, (3) soil flora.

Texture

Texture deals with the character of the particles which make up a soil, and with their arrangement in relation to each other. Clay soils are generally made up of very minute particles. Silt is made up of large grains. Coarse sand or gravel is composed of the largest grains. A soil is said to be porous when air or water can circulate through it freely. The porosity depends on the various proportions of clay, silt and sand which that soil contains. Plant growth, and incidentally plant health, is closely interwoven with the soil structure. Compact, sticky clays will be far more unfavorable to greenhouse crops than a clay loam.

The greenhouse man has the advantage over the ordinary farmer because he can modify the texture

of his soil so as to make it ideal for his crops. By combining the proper amounts of clay, silt, sand and humus, he may give to the plants a most congenial place to thrive in. To obtain such a result the gardener must exercise his best judgment. By varying the texture of the soil we may often influence the plants unfavorably. Flowering plants may be made to produce excessive foliage and few blossoms, while others may be differently affected.

Fertilizers

Crops require certain food elements to make growth possible at all, and they further require specific substances to enable them to accomplish definite purposes. The carnation, for instance, requires peculiar food elements to attain maximum growth. It further requires special nutritive elements to enable it to produce flowers and to avoid going altogether to foliage. The four leading plant foods needed by greenhouse crops are nitrogen, phosphorus, potassium and lime. All the other plant food elements are present in nearly all soils.

The effect of nitrogen is to stimulate leaf and stem growth, and to add green color. An overdose of it, however, may result in soft plant tissue, and thus retard fruiting. Acid phosphate stimulates root growth, and an overdose of it encourages an excess of root formation over foliage. Phosphorus also stimulates earliness in fruiting. The effect of potassium is to help the plant in assimilating other plant

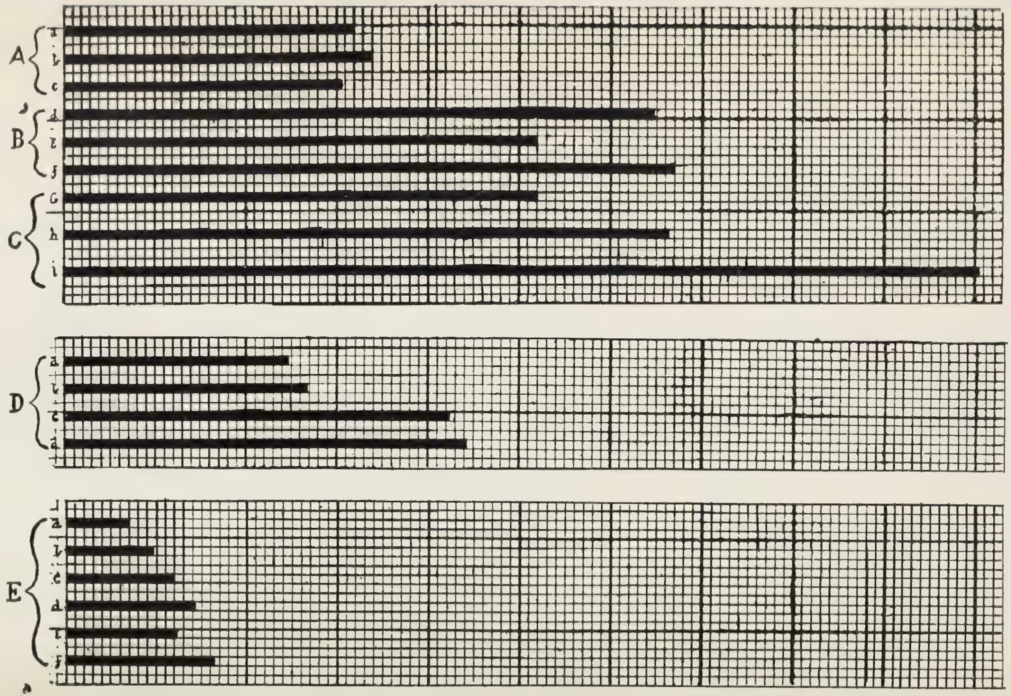

FIG. I. EFFECT OF FERTILIZERS AND WATERING ON THE YIELD OF LETTUCE.

A, B and C. *Chemical fertilizers versus stable manure.*

A
- *a.* Rich potting soil
- *b.* Raw bone meal
- *c.* Acid phosphate, nitrate of soda

B
- *d.* One-half manure
- *e.* Raw bone meal
- *f.* Raw bone meal, nitrate of soda and nitrate of potash

C
- *g.* Over one-half manure
- *h.* Raw bone meal
- *i.* Raw bone meal, nitrate of soda and muriate of potash

D. *Sulphate versus muriate of potash*

D
- *a.* Sulphate of potash
- *b.* Muriate of potash
- *c.* Sulphate of potash
- *d.* Muriate of potash

E. *Surface versus sub-watering*

E
- *a.* Surface watered
- *b.* Sub-watered
- *c.* Surface watered
- *d.* Sub-watered
- *e.* Surface watered
- *f.* Sub-watered (A-E after W. Stuart)

food, and indirectly in the manufacture of starch. It also encourages the production of finer plant tissue, thus increasing the plant's resistance to disease.

The aim of the greenhouse man is to produce early truck crops or cut flowers and this is directly concerned with feeding. Because the four plant food elements above mentioned are of extreme importance, their application cannot be indiscriminate. The greenhouse man must know how much of them to use in combination or separately. He must know also which element will especially benefit the particular crop with which he deals. In his investigations with the fertilizer requirements of lettuce, Stuart * reached the following conclusions: Potash when used in any considerable amount either alone or with nitrate of soda is unfavorable for growth (fig. 1, D.). Acid phosphate alone, in combination with nitrate of soda, or in combination with muriate of potash, stimulates growth (fig. 1, A, B, C.). For lettuce the use of chemical fertilizers proved slightly superior to stable manure, while nitrate of soda was found to be superior to dried blood. Wheeler and Adams,† in their work with radishes, found that an application of partially composted horse manure at the rate of 75 tons per acre gave better results than any other combination of fertilizers used. Working with carnations, Darner ‡ and his associates

* Stuart W., Indiana Agr. Expt. Sta. Bul. 84, Vol. 10: 115-142, 1900.

† Wheeler, H. J., and Adams, G. E., Rhode Island Agr. Expt. Sta. Bul. 128: 183-194, 1908.

‡ Darner, H. B., et al., Illinois Agr. Expt. Sta. Bul. 176: 365-386, 1914.

found that the use of nitrogen and acid phosphate caused an increase in the quantity and quality of the blossoms, but that the excessive use of potassium sulphate and dried blood would act injuriously on the plants. In his work on roses, Muncie * concluded that nitrogen in the form of farm manure, liquid manure or blood is very beneficial. The same seems also to be true for acid phosphate when used at the rate of 4 to 8 tons per acre. Lime should be added only when necessary to sweeten the soil. In this case, finely ground limestone may be used as a top dressing at the rate of 10 pounds per 100 square feet of bench space.

From the above discussion, it is evident that the proper handling of fertilizers underlies the success or failure of greenhouse crops. The cattleman, the poultryman, and others who deal with live stock now fully appreciate the importance of a properly balanced ration. Plants are similarly living organisms and consequently they too derive most benefit from a balanced ration (fig. 1, A.).

Aside from a consideration of the relation of the fertilizer to plant growth, its relationship to the soil must not be overlooked. Certain fertilizers, such as nitrate of soda, yield a residue of sodium, the accumulation of which sweetens the soil, and in the long run makes it alkaline. In clay soils serious physical effects may be the consequence. On the other hand, muriate and sulphate of potash, and sulphate of ammonia leave an acid residuum, the

*Muncie, F. W., Illinois Agr. Expt. Sta. Bul. 196: 511-564, 1917.

accumulation of which may render the soil sour. It therefore becomes imperative to so use or to so mix these fertilizers that their residues will combine and thus neutralize each other. One reason perhaps why greenhouse men favor the use of manure is that they have experienced the bad effects of the residue of improperly mixed fertilizers.

Soil Flora

By a soil flora is meant the bacteria or fungi, whether beneficial or harmful, which thrive in that soil. Science has proved definitely that a soil can no longer be regarded as a conglomeration of dead, inert particles of rock. The soil teems with life which to a large extent determines its fertility. The more numerous the beneficial bacteria and fungi it contains, the more fertile it will be. On the other hand if the beneficial micro-organisms are absent, or perform their work imperfectly, or if the soil is overridden by harmful parasitic bacteria or fungi, we speak of it as a sterile or sick soil. In the greenhouse, the soil flora is often entirely different from what it is outdoors. This is due to the fact that the soil is artificially made up of a mixture of various ingredients with the object of making it ideal for plant growth. It is imperative that the greenhouse manager possess some knowledge of bacteria and fungi, and that he understand the functions and the requirements of the soil micro-organisms, if he wishes

to secure proper control of his soil and to make it ideal for plant growth.

A. Bacteria. Bacteria are minute microscopical plants that consist of a single cell. They are composed of a cell wall of protoplasm and average about 1/25000 of an inch in length. These simple organisms multiply by fission, that is, the original mother cell divides in two equal parts, which may separate or remain united, giving the appearance of a thread. It has been estimated that a single bacterium divides about every twenty minutes. Granting that this rate of division is uninterrupted for twenty-four hours, the descendants of a single one within a day would be in round numbers 1,800,999 trillions. These when placed end to end would make a string two trillion miles long, or a thread long enough to go around the earth at the equator 70,000,000 times. However, multiplication at such a rate cannot occur because food conditions are restricted. The three main types of bacteria are: 1. the cocci, 2. the bacilli or rods, 3. the spirilla or spirals (fig. 2, c.). The greater number of the soil bacteria are beneficial, the most common being the saprophytes, or those which help to decay the dead organic matter from either animal or plant. The parasites on the other hand are those which produce disease.

B. Fungi. Fungi are low forms of microscopic plants, of a slightly higher type than bacteria. Fungi are made up of colorless feeding threads technically known as hyphæ or mycelium. The spores which correspond to the seed of the higher plants are borne

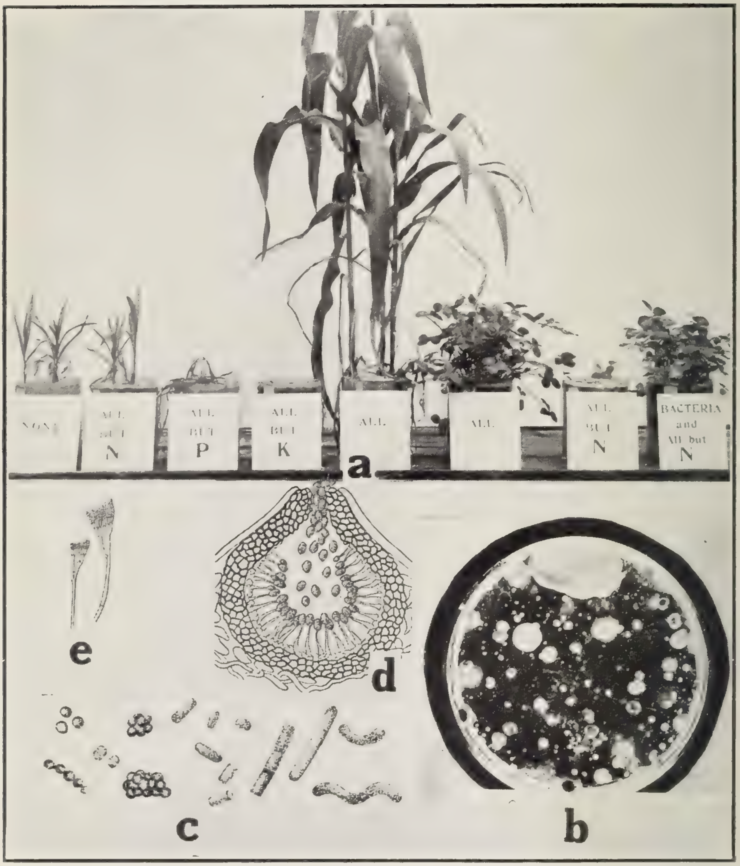

FIG. 2.

a. Effect of a balanced fertilizer on corn and clover, *b.* various organisms isolated from a soil particle, *c.* types of bacteria, Coccus, Bacillus and Spirilla (after P. E. Brown); *d.* pycnidium (after C. L. Shear), *e.* conidiophores of Penicillium.

either in sacs, known as pycnidia (fig. 2, d) or on free stalks, known as conidiophores, meaning stalk bearing spores (fig. 2, e.). Fungi, like bacteria, depend on animals or plants for their food. Like bacteria, they are differentiated into saprophytes and parasites.

Relationship of Micro-organisms to the Fertility of a Soil

Bacteriologists are continually engaged in discovering the possible function of numerous groups of the soil organisms. A recent exhaustive study * of Actinomyces, or thread bacteria, in the soil, for instance, seems to show that they serve to decompose grass roots, being more numerous in sod than in cultivated land. Other groups of bacteria undoubtedly perform other important functions.

The mere presence of friendly micro-organisms in the soil, however, would be insufficient to assure the welfare of our cultivated lands. These minute organisms must find the conditions necessary to induce a maximum activity in the performance of their work, which is to act as chief cook in the dietary of the plant. Most of the plant's food, as it is found in the soil, is in a crude and unavailable form. The bits of mineral matter, the manure, or fertilizer added to the greenhouse soil, all contain plant foods, but in a form which plants cannot readily

*Conn, Joel H., New York (Geneva), Agr. Expt. Sta. Bul. 52: 3-11, 1916.

use. They must be softened and predigested, and this work is done by the friendly micro-organisms. The supply of plant food is therefore directly dependent on the work of these minute scavengers. An intimate relation exists between the higher and the lower form of plant life, the one depending on the other for sustenance.

A. NUMBER OF MICRO-ORGANISMS IN SOIL. Investigations by Waksman * and others clearly show that micro-organisms are present in soils everywhere (see Table I and fig. 2, b).

It should be remembered that differences in the physical and chemical nature of the greenhouse soil, the sort of fertilizers used and the amount of temperature and moisture will all be important factors in determining the number of micro-organisms present.

NATURE AND FUNCTION OF A HEALTHY SOIL FLORA

The function of a normal soil is to provide available plant food. About 95 per cent of the weight of a growing plant is made up of carbon, hydrogen, oxygen and nitrogen. The remaining 5 per cent constitutes the mineral or the non-combustible part or ash of the plant. Carbon, hydrogen, and oxygen are absorbed in the form of carbonic acid and water; nitrogen is usually derived from nitrates produced by micro-organisms out of organic matter in the soil. Neither the organic nor the mineral elements are in

*Waksman, L. A., Soil Science, 3: 565-589, 1917.

TABLE 1

Source of Soil Used	*Bacteria*	*Actinomyces or Thread Bacteria*	*Fungi*
New Jersey garden.........	7,202,000	711,000	313,000
New Jersey orchard.........	8,257,000	611,000	375,000
New Jersey meadow........	10,133,000	900,000	925,000
New Jersey forest..........	2,088,000	20,000	218,000
New Jersey muck..........	2,600,000	....	150,000
Milltown bogs.............	185,000	....	33,000
Buckalew bogs.............	450,000	12,000	43,000
Iowa soils.................	220,000	281,000	113,000
Louisiana soil..............	10,000,000	2,000,000	119,000
California fertilized.........	3,840,000	680,000	108,000
California unfertilized.......	6,444,000	356,000	36,000
Oregon muck..............	7,900,000	1,400,000	400,000
Oregon white land..........	3,400,000	300,000	300,000
Porto Rico soil............	2,140,000	960,000	300,000
North Dakota wheat........	2,070,000	933,000	30,000
North Dakota flax..........	1,730,000	263,000	23,000
Hawaiian soil..............	4,335,000	665,000	76,000
Alaska soil................	6,035,000	566,000	330,000
Texas soil.................	2,125,000	574,000	30,000
Colorado soil..............	2,440,000	1,560,000	230,000
Maine Aroostook loam......	4,650,000	250,000	85,000
Maine Aroostook infested....	15,000,000	2,200,000	300,000
Canada soil................	1,600,000	1,100,000	112,000

a form which plants can use. They must at first be acted upon by certain definite micro-organisms in the soil.

A. The Transformation of Carbon. Cellulose, which is but a form of carbon, constitutes a large per cent of the woody tissue of plants. Soils contain large amounts of cellulose and this undoubtedly helps to maintain their proper physical condition. It is found in large quantities in straw, manure, or in green vegetable matter. But because of its complex form, plants cannot make use of it, until it undergoes a certain decomposition. This is accomplished by a group of soil bacteria known as Amylobacter, which, feeding on the dead vegetable cellulose, break it up, and reduce it to carbon dioxide, hydrogen and fatty acids. The carbon dioxide either returns to the air to replenish the atmospheric supply, or it unites with water to form carbonic acid and soil carbonates. The carbon dioxide is taken by the plants either directly from the air through the leaves, or from the soil in some carbonate form. Thus we see that it is not the cellulose nor the product of its decomposition that furnishes plant food, but certain inorganic elements which are set free in its decomposition.

B. Elaboration of Available Nitrogen. From the viewpoint of plant nutrition, nitrogen is unquestionably the most important of all elements. The nitrogen of the air, although totaling about 79 per cent of it, is not in an available form. In the transformation of proteids into available nitrogen in

the soil, three definite processes take place, all thanks to the work of certain soil micro-organisms.

1. *Ammonification.* In this process, the soil bacteria attack the complex proteids and convert them into ammonia. The odor of ammonia from decomposed urea, manure, or any other organic matter is always an indication that ammonification takes place. According to Sackett * and others the ability to bring about this change is attributed to the following soil bacteria: *Bacillus mycoides*, *Bacillus proteus vulgaris*, *Bacillus mesentericus vulgatus*, *Bacillus subtilis*, *Bacillus janthinus*, *Bacillus coli communis*, *Bacillus megatherium*, *Bacillus fluorescens liquefaciens*, *Bacillus fluorescens putidus* and *Sarcina lutea.*

Recent investigations by Waksman † and others indicate that certain classes of fungi are even stronger ammonifiers than are bacteria. *Trichoderma Koningi* and the Mucorales fungi were found to be strong ammonifiers. Fungi, too, are very strong cellulose decomposers. Further extensive investigations on soil fungi will no doubt more strongly establish their relationship to ammonification.

2. *Nitrification.* In order to be readily available for plants, ammonia and ammonia compounds must be changed still further into simpler compounds or, as the process is known, must undergo nitrification. The ammonia is first oxidized into nitrous acid and nitrates. This is accomplished by soil bacteria, Ni-

*Sackett, W. G., Colorado Agr. Expt. Sta. Bul. 196: 3-39, 1916.
† Waksman, A., Soil Science 2: 103-155, 1916.

trosomonas and Nitrosocoscus. The nitrates are then oxidized into nitric acid and nitrates, through the work of the bacterium, Nitrobacter. The nitrates are the only forms of nitrogen which plants can use.

C. Action of Soil Flora on Mineral Substances. Inert mineral substances, like the organic matter in the soil, must first be acted upon by certain soil bacteria to be converted to a form which plants can readily assimilate.

1. *Changes of Phosphates.* Phosphates as they commonly occur in nature are but little soluble in water. This is why they cannot be used in their first form, although they are required by most plants. Soils deficient in this element may be improved by such fertilizers as superphosphate of lime, ground bone, phosphate rock or Thomas slag. In the process of decomposition of organic matter a large quantity of carbon dioxide is liberated, which unites with the water in the soil to form carbonic acid. This acid attacks the insoluble phosphates, transforms them into superphosphates—the only form soluble in water,—and renders them available to plant life.

2. *Changes in Potassium, Sulphur, and Iron.* The carbon dioxide and other organic acids produced during the fermentation of organic matter, attack the potash feldspar which occurs in the soil. The product is potassium carbonate which is soluble in water and hence readily taken up by plants. The nitric acid which is formed during nitrification may also combine with the raw pot-

ash in the soil, forming potassium nitrate which is a form available for plants.

As a result of the activity of soil bacteria, hydrogen sulphate is evolved from the decomposition of proteids. The sulphur may be further changed into sulphur dioxide, and when combining with water and oxygen, into free sulphuric acid. The latter readily combines with calcium or magnesium, forming calcium or magnesium sulphate, from which the plant obtains sulphur for the construction of its proteids.

CHAPTER 2

SICK SOILS

When a soil is sick, either because its beneficial bacteria do not perform their functions properly, or because of abnormalities in its chemical or physical properties, careful treatment and proper cultural methods may restore it to health. But when a soil becomes sick and unproductive because parasitic forms gain a foothold in it, much greater skill and knowledge are required to cope with the problem. Its solution is of the greatest economic importance to the gardener and to the greenhouse man.

Parasitic fungi, upon finding their way into a soil, do not necessarily interfere with the work of the beneficial bacteria, such as the ammonifiers and nitrifiers, for instance. Nor do they always influence the chemical or physical nature of the soil. Many of them directly attack the crop itself, causing serious diseases in the plants.

Damping Off

This disease is very familiar to every grower of plants. It is peculiar to seedlings or tender plants, and is very prevalent in the greenhouse, the hot bed,

the cold frame as well as in the field. It is induced by the presence of definite parasitic fungi, which thrive best in overwatered soils, and when the greenhouse is kept at a comparatively high temperature with poor ventilation. Damping off is also favored by thick sowing and too much shade in the seed bed.

Symptoms of Damping Off. Every experienced grower knows the disease when he sees it. Seedlings freshly damped off are soft and water soaked at the base of the stem. If they are pulled they often break off easily. A more careful examination shows that the root system is entirely decayed, although the upper part of the stem and leaves may still be green, and also possibly fresh. The degree of prostration in the seedlings is determined by the amount of moisture in the soil. If it is slight, the seedlings will become flabby and wilted before they topple over. With a high moisture content, they are more firm, but become prostrate as soon as infection sets in. The trouble usually begins in spots in the bed, thence spreading in every direction. Damping off is usually caused by several fungi, the chief of which is *Pythium de Baryanum* Hesse. The organism was first named and described by Hesse in 1874. Ward * found it to be a very prevalent parasite in the garden soils of Europe. In America the fungus was first recognized as of great economic importance by Atkinson.† The seedlings of most

*Ward, M., Quart. Jour. Micros. Soc. New Ser. 22: 487, 1883.
† Atkinson, G. F., New York (Cornell) Agr. Expt. Sta. Bul. 94: 233-272, 1895.

greenhouse plants may become subject to damping off by Pythium. When examined under a compound microscope, *Pythium de Baryanum* is seen to be made up of coarse non-separate, highly granular, irregularly branched hyaline vegetative threads or mycelium. The younger growing threads are more finely granular. The oldest are coarsely granular or more often empty. These threads penetrate the cells of the host, where they obtain its food.

Pythium de Baryanum does not often fruit on the dead seedlings. The fruiting is better observed when the fungus is grown in pure culture. Under normal conditions it produces two forms of spores, conidia and oogonia. The summer spores, or conidia, are swellings formed at the tip of the hyphæ (fig. 3, a.). These swellings readily break off from the mother threads and germinate by sending out a slender tube. This tube penetrates the seedling tissue where it grows and develops and after due incubation reproduces the disease. The oospore, or sexual spore, is the stage which is most commonly found. The female organ (oogonium) first develops as a terminal enlargement which is cut off by a septum from the mother thread. Next or adjacent to it a slender tube is cut off from the mycelium by a septum. This tube performs the function of the male sexual organ and is known as antheridium. The latter then comes into close contact and empties all its content into the female oogonium (fig. 3, b and c.). Fertilization thus takes place, and a mature egg, or oospore, or winter resting spore is formed.

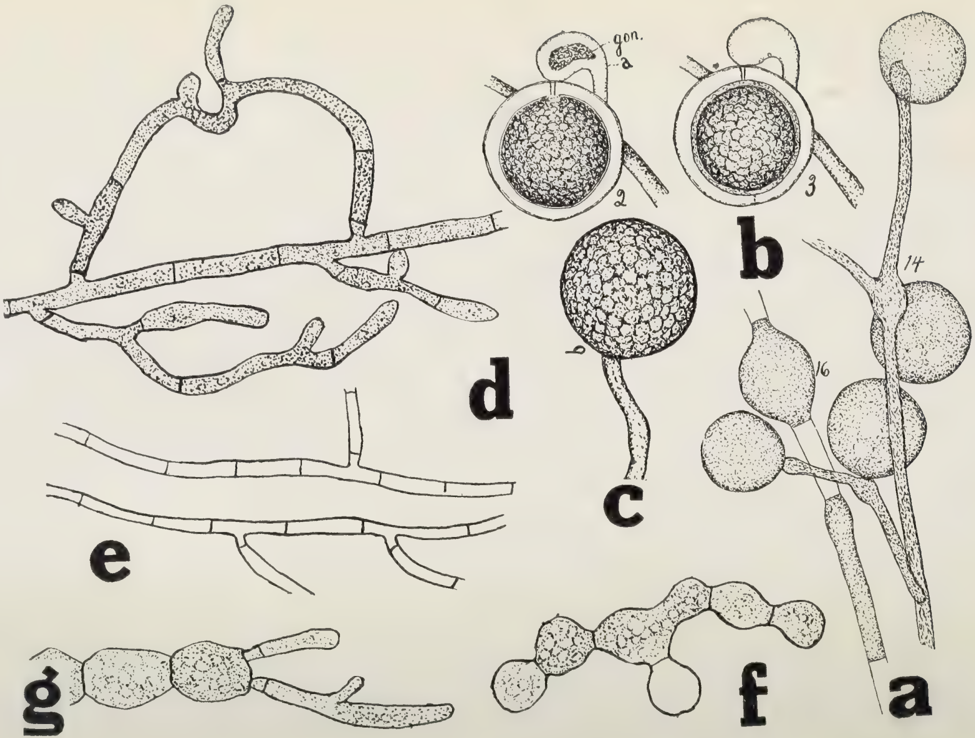

FIG. 3.

a. Conidiophore and conidia of Pythium, *b*. fertilization in Pythium, *c*. oögonium (a-c after Atkinson), *d-c*. mycelial threads of Rhizoctonia, *f*. barrel-shaped cells of Rhizoctonia, *g*. germinated barrel-shaped cells (*d-g* after Peltier).

The latest investigations have not yet disclosed whether or not *Pythium de Baryanum* is carried over from year to year by its oospores. It is apparently able to propagate itself indefinitely by its vegetative mycelium.

Of the other fungi which are capable of producing a damping off in the greenhouse or seed bed may be mentioned *Sclerotinia libertiana* Fckl., *Phoma solani Halst.*, Colletotrichum sp., Fusarium sp., *Sclerotium rolfsii* Sacc. and *Rhizoctonia solani* Kuhn. Each of these, except the last, will be taken up separately in connection with the study of their respective hosts.

The fungi which cause damping off are introduced into the greenhouse, primarily with sick soil used in the compost, and also with infected manure. The practice of dumping diseased plants and all other infected material in the manure pile cannot be too strongly condemned. Sometimes very lightly infected plants with no visible symptoms of disease in the seed bed may nevertheless act as carriers, and likewise infect the greenhouse soil.

Damping Off of Cuttings

Greenhouse men are often troubled with a damping off of cuttings. In specific cases this is brought about by parasitic fungi which, however, will be taken up at length under the discussion of the various hosts.

Root Rot

Caused by *Rhizoctonia solani* Kuhn.

Although not so virulent as Pythium, Rhizoctonia is a frequent cause of considerable failure in greenhouse culture. The fungus causes a damping off of seedlings and cuttings and a serious root rot.

Symptoms. The symptoms of Rhizoctonia rot or wilt do not differ materially from those produced by *Pythium de Baryanum.* On older plants, however, Rhizoctonia produces cankers or deep lesions which are very characteristic. These are formed on the roots as well as on the base of the stem. The lesions are reddish brown and extend into the cortical or vital layer as well as into the woody tissue. There is perhaps no other parasitic fungus which is so widespread and which is capable of attacking such a variety of hosts as Rhizoctonia. The work of Peltier * shows that the following greenhouse crops are susceptible to Rhizoctonia: beet, bean, cauliflower, celery, cucumber, egg plant, horseradish, lettuce, muskmelon, pepper, radish, tomato, sweet alyssum, amaranthus, ornamental asparagus, china aster, begonia, candytuft, carnation, coleus, dianthus, lavatera, lobelia, pansy, poinsettia, sweet pea, violet.

Cuttings of the following hosts are also reported by Peltier to damp off from Rhizoctonia: Abutilon hybridum, var. lavitzii, Acalypha wilkesiana, var.

* Peltier, G. L., Illinois Agr. Expt. Sta., Bul. 189: 283-391, 1916.

bicolor, A. wilkesiana, var. tricolor; A. wilkesiana, var. marginata, Ageratum mexicanum, Alyssum odoratum; Coleus, Cuphea phatycentra, Tresine, Petunia, Piguerua trinervia, Lautolina chamoecyparissus, Sedum spectabile, Althernanthera, Vincia major.

The Organism. In the United States the first extended account of Rhizoctonia was given by Pammel.* Many other excellent accounts by American workers have appeared from time to time, to which we shall have occasion to refer later.

The genus Rhizoctonia includes several forms of sterile fungi, all of which are distinguished by the manner of growth in pure culture, and by its mycelium. Young hyphæ of *R. solani* Kuhn are at first hyaline, then deepening in color from a yellowish to a deep brown. The young branches are somewhat narrowed at their point of union with the parent hyphæ and grow in a direction almost parallel with each other. A septum is also laid down at a short distance from the point of union with the parent mycelium (fig. 3, d and e.). There is another form of hypha which is made up of barrel shaped cells (fig. 3, f.), each of which is capable of germinating like a spore. In pure cultures *R. solani* produces sclerotia which are first soft, whitish, and which later become hard and dark. The fungus is carried over from year to year as sclerotia which are able to withstand the effects of heat, cold, drought, or moisture.

*Pammel, L. H., Iowa Agr. Expt. Sta., Bul. 15: 244-251, 1891.

Parasitic Soil Fusaria

Next in importance to Rhizoctonia is a group of fungi which belong to the genus Fusarium. Soils infected with these species of fungi become unfit for tomatoes, sweet peas, etc., thereby causing great financial losses to the greenhouse man. Individual difficulties will be taken up in studying each of these crops separately. As an illustration of a typical Fusarium sick soil let us consider the wilt of sweet pea. The cause of this trouble is a soil inhabiting fungus, *Fusarium lathyri* Taub.

Symptoms. The first symptom of the disease is a sudden flagging of the leaves, accompanied by general wilting and collapse of the seedling. Usually upon sowing the seeds a fair percentage germinate and reach the height of about 8 to 10 inches before they are attacked by the fungus (fig. 7, b.). If the collapsed seedlings are allowed to remain on the ground, the stems will soon be covered with the sickle shaped spores. Eventually the decayed tissue rots and is soon invaded by small fruit flies which now begin to distribute the fungus from place to place by carrying its spores.

The Organism. The mycelium of *Fusarium lathyri* is hyaline, septate and branched. At an early age the mycelial cells round up into countless numbers of chlamydospores. Old cultures are practically one mass of these resting bodies. The spores are of two sorts, the macroconidia which are sickle shaped,

3-4 septate, the microconidia are one celled, minute spherical to elliptical.

SOILS RENDERED SICK BY CERTAIN FORMS OF ANIMAL LIFE. Some soils are made sick by the presence of minute forms of animal life. A striking instance of this is the root knot, a disease produced by a little worm generally known as nematode, or eel worm.

ROOT KNOT

Caused by *Heterodera radicicola* (Greef) Mull.

Although root knot is most prevalent in light soils, it may sometimes be found in heavier lands. The trouble is most widespread out of doors in the Southern States, where the winter is mild. In the North the worm is usually unable to winter over in the open unless it is protected by trash or dead weeds. It is, however, prevalent in greenhouses and is undoubtedly introduced with sick soil brought in from the field.

Symptoms. The disease is characterized by swellings or knots on the roots. These swellings may be variously shaped, and are often mistaken for the true nodules of legumes (fig. 22.). Infected plants become stunted, pale, and usually linger for a long time before dying.

The Organism. The nematode is a very minute worm, seldom exceeding one twenty-fifth of an inch in length. It is semi-transparent so that it cannot be easily detected by the naked eye. In searching for the eel worm, it is necessary to break a fresh knot

(fig. 4, a-e.). Close examination will reveal two types of worms; a spindle shaped worm, the male, and a pearly white pear shaped organism, the female, firmly embedded in the gall tissue. The female is very prolific, depositing no less than 400 to 500 eggs during her lifetime. The eggs are whitish, semi-transparent, bean shaped bodies, and too small to be noticed without the aid of a magnifying glass (fig. 4, f.). The time which elapses until the eggs hatch (fig. 4, f-u) depends largely upon weather conditions. In warm days the eggs hatch sooner than in cold days. Upon hatching, the young larvæ either remain in the tissue of the host plant in which they emerge, or, as is more often the case, leave the host and enter the soil. This is the only period during which the worms move about to any great extent in the soil, where they either remain for some length of time or immediately penetrate another root of the host. The nematodes in most cases become completely buried in the root tissue, establishing themselves in the soft cellular structure which is rich in food. The head of the worm is provided with a boring apparatus consisting of a sharply pointed spear, located in the mouth. This structure not only aids it in getting food but is also valuable in helping the young worms to batter through the cell walls before becoming definitely located. The two sexes during the development are indistinguishable up to fifteen or twenty days, both being spindle shaped. In the molting or shedding of the skin, there is a marked change in the case of the

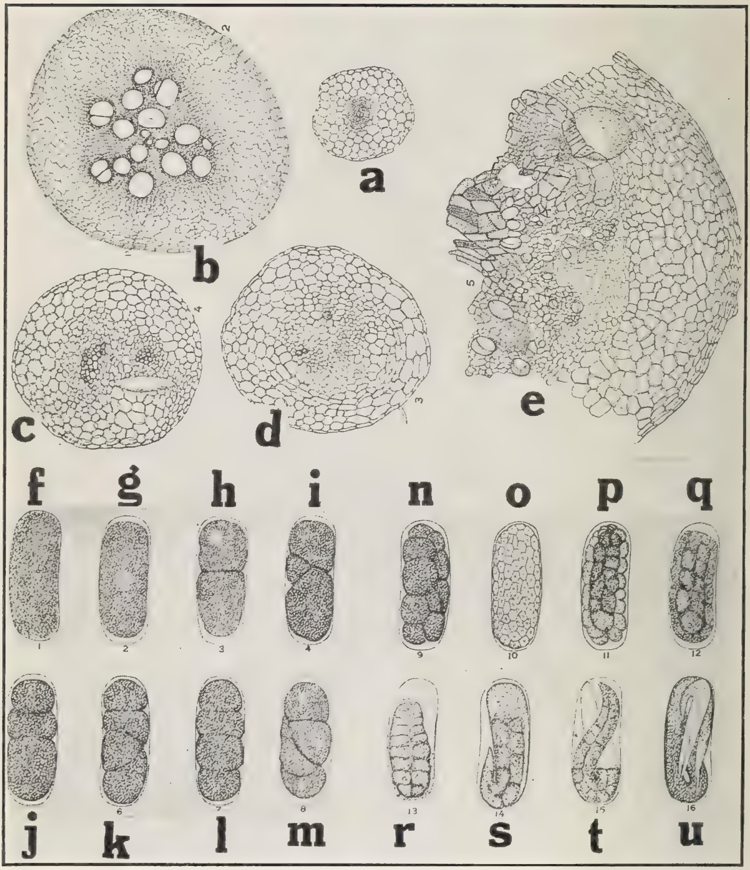

FIG. 4. NEMATODE.

a. Very young, normal root, *b*. mature, normal root, *d*. young root same age, *c*. attacked by nematodes, *d*. same, one week later, *e*. section of mature gall, showing distortion of tissue, *f-u*. the various stages of development of the young embryo worm, beginning with *f*, as the egg and ending with *u* as the mature worm ready to hatch (*a-u* after G. E. Stone and R. E. Smith).

female, especially in the posterior region of the body, which no longer possesses a tail-like appendage. Fertilization occurs soon after this molt, and many radical changes occur in the shape and structure of the organization of the worm. The fertilized female increases rapidly in breadth and becomes a pearly white flask or pear-shaped individual. At this stage it is far from being worm-like and may, therefore, be overlooked by one unfamiliar with the life-history of the eel worm. The young male is much like that of the young female larvæ, being spindle shaped in outline. The male does not cause as much damage to the root tissue as the female, and its purpose in life seems to be only that of fertilizing the female, for after this function has been performed, it is quite probable that the male worm takes no more food.

Omnivorous Nature of the Eel Worm. There are two hundred and thirty-five species of plants known to suffer from the eel worm. This number includes all the important families of the flowering plants. According to Bessey * the following are among the greenhouse plants subject to root knot: bean, beet, cantaloupe, cauliflower, cucumber, egg-plant, lettuce, radish, tomato. For methods of control, see p. 40.

Leaf Blight Nematode

Caused by *Aphelenchus olesistus* Rizema-Bos.

Beside the root knot disease which is caused by

*Bessey, E. A., U. S. Dept. Agr. Bureau Pl. Ind. Bul., 217: 7-89, 1911.

Heterodera radicicola there is another nematode which confines its injury to foliage only.

Of the greenhouse hosts affected by this pest may be mentioned the Begonia, Asplenium nidus-avis, Pteris serrulata avistata, Pteris wimeseth, Pteris tremula, and Pelargonium.

Symptoms. On the Cincinnati begonia the symptoms, according to Clinton,* are manifested as numerous small indistinct discolorations limited by the small veinlets. In time, however, the tiny spots enlarge and unite, forming a conspicuous reddish-brown blotch. Frequently infection is manifested as long streaks along the main veins. Often isolated spots occur in the midst of the surrounding healthy tissue (fig. 5, a.). On Asplenium nidus-avis, the trouble becomes conspicuous in dark brown areas from the base of the leaf near the midrib. These spread upward until the entire lower half of the leaf is killed. On Pteris, the spots appear as reddish brown bands reaching out from the midrib to the border, but limited sidewise by the small parallel cross veins (fig. 5, b.).

The Organism. The nematode in question is a slender microscopical worm. The latter chooses the air chamber of the leaf in which to lay its eggs and upon hatching travels around in different parts of the same leaf or to the neighboring foliage. The worm can travel only when there is a wet film on the leaves.

*Clinton, G. P., Connecticut Agr. Expt. Sta., Thirty-ninth Ann. Rept.: 455-462, 1916.

Fig. 5. Leaf Blight Nematode.

a. Infected begonia foliage, *b*. the blight on fern leaves (*a-b*, after Clinton).

Control. Immersing fern plants for five minutes in water heated to 122 degrees F. (50 degrees C.) does not seem to injure the ferns, but seems to kill the nematode. All infected leaves should be cut off and burned. Diseased plants should be isolated from healthy ones. Spraying with Bordeaux may also act as a repellant.

CHAPTER 3

TREATMENT OF SICK SOILS

Our conception of a healthy soil as has been indicated is one which is ideally suited to plant growth, through proper physical and chemical make-up, and by the presence of groups of beneficial micro-organisms. A sick soil is one in which plants would grow very languidly or not at all. Soil sickness may be caused through the improper use of fertilizers, or through the introduction of parasitic disease-producing organisms.

Acid-Sick Soils

Soils which contain an excess of acid, in which crops refuse to grow, may be termed acid-sick. Acids in soils have a directly poisonous effect on plants. Soil acidity may be brought about by the loss of lime and of other bases; and by the decomposition of organic and of inorganic matter.

Crops are known to draw heavily on the lime of the soil, and thus to increase the proportion of acidity. This, then, is one direct way of depleting the soil lime. Lime and other bases are further lost from the soil by leaching. The soluble carbonates are but slowly soluble in pure water. However, carbon dioxide, nearly always present in soils,

changes the calcium carbonate into calcium bicarbonate, which is very soluble, and readily leaches out with the drainage water.

Soils which are heavily manured are apt to become more acid. The decomposition of the organic matter yields large quantities of carbon dioxide which act on the carbonate in the manner above indicated. In addition to these causes, poor drainage has a tendency to increase the soil acidity. The application of ammonium sulphate as a fertilizer leads to a development of acidity by the production of sulphuric acid. The same is true when other acid fertilizers are used. In the process of nitrification, in which nitrogen is made more available for plants, acids are produced. Acidity in a soil is usually characterized by a languid condition of the growing crop. This may be due directly to the effect of the acid on the plants, or to the inhibiting effect of the acid on the soil flora. In the latter case the plant food in the soil, although very plentiful, may not be in a form available for plants.

Not all crops are equally sensitive to soil acidity. Hartwell and Damon* have determined the degree in which truck crops are benefited by the application of lime to an acid soil. Those which are very sensitive to soil acidity are followed by the number (3), while a lesser degree of sensitiveness is indicated by the numbers (2) and (1). Crops which tolerate a moderate amount of acidity are followed

*Hartwell, B. L., and Damon, S. C., Rhode Island Agr. Expt. Sta. Bul. 160: 408-446, 1914.

by the figure (0), and those which thrive best in acid soils (—1); beans (0), beets (3), carrots (1), cauliflower (2), celery (3), cucumber (1), egg-plant (2), lettuce (3), muskmelon (0), parsley (0), pea, garden (1), pepper (3), radish (1), rhubarb (3), sorrel (—1), spinach (3).

Treatment of Acid Soils

The best known remedy for soil acidity is lime. Its effect is to neutralize the acidity, and to restore the normal equilibrium for the activity of the soil flora, thus overcoming the antagonism to normal growth. The amount of lime to be used depends on the kind of soil, its degree of acidity, and the crops grown. It is very unlikely that injury would result to greenhouse crops from the use of moderate amounts of lime. Lime is sold as ground limestone or as burned lime. A ton of burned limestone will yield 1,120 pounds. If enough water is added, it will weigh 1,480 pounds. If 1,120 pounds of burned lime or the 1,480 pounds of hydrated lime are allowed to air slack, the weight of both will be 2,000 pounds. Air slacked lime has the same composition as ground limestone. In buying hydrated lime we do not get any better quality, but merely pay an excess in freight for the amount of water it contains. The cost of delivery should determine the kind of lime to buy.

Wood ashes may often be used instead of lime to correct soil acidity. Hardwood ashes contain about 30 per cent. lime and 60 per cent. potash.

Two and a half tons of good wood ashes are equivalent to one ton of burned lime for overcoming soil acidity. Leached ashes have lost their potash and its lime is in the form of a hydrate or carbonate.

Magnesium lime, which contains a high percentage of magnesia, is not objectionable for use. In fact, a ton of limestone, which contains magnesium carbonate is more effective on acid soil than a ton of limestone without magnesium carbonate. Lime should be applied only when the acidity of the soil requires it.

Alkali Soils

Alkali soils are termed sick, since plants thrive there poorly or not at all. The alkali problem generally concerns only those greenhouse men located in the irrigated districts of the arid or semi-arid regions of the United States.

For convenience, alkali soils are here divided into black and white. The black alkali lands are known to contain sodium carbonate or washing soda as the essential salt. The latter does not act so much on the soil as on the organic matter, turning it black. This dark material is always found on the surface with the salts. The blackening of the soil, however, is not always an indication of black alkali. Many dark spots are found to contain the white alkali. Moreover, soils which contain little or no organic matter may contain large quantities of sodium carbonate and never turn black. The white alkali in reality is not a true alkali. The salts found in it

are sodium chloride or table salt, calcium sulphate or gypsum, sodium sulphate, magnesium sulphate or epsom salt. In addition to these may be found salts of potassium.

Methods of Control. Generally speaking the alkali problem is not serious in greenhouse culture. The alkali soil when mixed at the compost heap generally loses much of its salts due to the action of the manure used. However, in alkali regions alkali soils should be avoided as much as possible. When this is not possible the soil to be used with the compost should be spread out and exposed to the action of winter weather conditions and to the washing by rain. This treatment will result in a loss of the injurious salts through leaching.

Soil Sterilization

Damping off, whether induced by Pythium, Rhizoctonia or any other parasitic organism, is usually confined to seedlings in the seed bed under cover or in the open. The loss of seedling not only means a waste of seeds, but it also results in poor stands. The disease-producing-organisms are usually brought in with the manure and the compost. Most growers are in the habit of using the same soil in the seed bed or in the greenhouse year in and year out. A number make it a practice to empty their beds and use fresh soil every year. This, however, is too expensive and, moreover, is not always a safe method, for the new soil, too, may be contaminated, or may become infected as soon as it is placed in the

bed previously contaminated. Fortunately, sick soils in the greenhouse, unlike the soil outdoors, may be readily treated so as to destroy all forms of parasitic micro-organisms or injurious animal life which are present in it. The various methods to be mentioned make it possible to use the soil over and again. Rid the soil of parasites, then all chances will be in favor of good crops whether vegetables or flowers.

Soil Treatment with Formaldehyde

When steam sterilization is not feasible, because of the absence of suitable steam pressure, the formaldehyde treatment is the next best. With this method we may control Fusarium, Rhizoctonia, and Pythium in infected beds. It is doubtful, however, if it will entirely eradicate eel worms from infested soils. The method is as follows: the beds are thoroughly prepared in the usual way with all fertilizers worked in and then the soil is drenched with a solution of formaldehyde composed of one pint of the chemical (40 per cent. pure) to 30 gallons of water applied at the rate of one gallon per square foot. The solution should be put on with a watering can and distributed as evenly as possible over the bed, so as to wet the soil thoroughly to a depth of one foot. It will, in most cases, be necessary to apply the solution in two or three intervals, as the soil may not absorb the full quantity of the liquid at one time. After treatment the beds should be cov-

ered with heavy burlap to retain the formaldehyde fumes for a day or two, and then aired for a week before planting. Stirring the soil at frequent intervals after uncovering hastens the more rapid escape of the formaldehyde fumes.

Sterilizing Soils with Steam

Steam sterilization of soils is by far the best method. There are four ways of steaming soils: (1) Inverted pan method, (2) the perforated pipe system, (3) the steam rake device, (4) the drain tile method. The choice of any one of these methods is a matter of expediency. All four methods have been successfully used on a commercial scale.

The Inverted Pan Method. This was first devised by A. D. Shamel of the U. S. Department of Agriculture. To carry it out, the boiler must maintain a pressure of not less than 80 pounds, for at least one and a half hours. In setting a pan, the rim is sunk into the soil of the seed bed or bench, to a depth of two to three inches, to make the inclosed chamber steam tight. In heavy soil, trenching may be necessary. It is also advisable to put a heavy weight on the pan when the steam operates. For one pan, a traction engine or a portable boiler of ten to twelve H. P. will suffice. While the standard of the pan is six by eight feet, the dimensions may be modified to suit the seed beds or greenhouse benches.

Selby and Humbert* describe the method of constructing an inverted pan as follows:

"Material used for construction of a pan is galvanized sheet iron; the most useful weight is No. 20 gauge, which weighs 26.5 ounces per square foot. The heavier material requires little in the way of frame supports. The galvanized iron sheets come in sizes varying from two to three feet in width by eight to ten feet in length. The standard is a pan 6 x 10 feet in area, six inches deep, constructed from 5 such strips 2½ x 8 feet in size. These sheets are joined by double fold seam and riveted at intervals of 6 to 10 inches to make the pan steam tight. This pan is further strengthened by a band of strap iron 2 x 1 inch riveted to the bottom edge, and stiffened by a brace of 1¼-inch angle iron across the top and extending down the sides. This is bolted at the sides to the supporting strap iron stiffener.

"The entrance pipe for the steam may be placed at the side or end of the pan or may enter from the top. The latter form has the advantage in that it will not interfere with the box boards when used on frames. The pipe, after entrance, should be a T form, so that steam in being forced into the pan when in place does not blow holes in the soil."

The pans, together with the sand bags used for weight, are mounted on a frame which rests upon wheels. The wheels run on the edges of the con-

*Selby, A. D., and Humbert, J. G., Ohio Agr. Expt. Sta. Circ. 151: 65-74, 1915.

crete walks on either side of the house. By using a pulley, the pan may be conveniently placed wherever desired.

Perforated Pipe Method. The apparatus consists of a set of perforated pipes buried in the soil and connected with a steam boiler. The main and cross-head pipes are 2 inches and those which are buried 1½ inches. The length of the beds, and especially the capacity of the boiler, will determine the number of pipes to use. However, 7 to 8 pipes are as many as could be used to advantage. These should not be over 40 feet long. The perforations should be one-eighth to three-sixteenths of an inch in size, 12 to 15 inches apart and on the upper side of the pipes. The latter are buried about six inches deep and when the steam is turned on the beds are covered with a heavy canvas to retain the heat and to prevent the escape of steam (fig. 6, a and b.). Whenever convenient, it is well to have two sets of pipes so as to save time and fuel.

Steam Rake Method. This consists of a two-inch main pipe which may be run between two sets of houses. The pipe is connected with the boiler at one end and with a heavy hose at the other. The rake is attached to the hose through which the steam is introduced. There are either two rakes used in a single house, or four rakes operated in pairs, end to end in two adjoining houses. The rake is generally composed of three main pipes 13 feet long, which run crossways of the house, and of several cross pieces one inch in diameter that are gradually

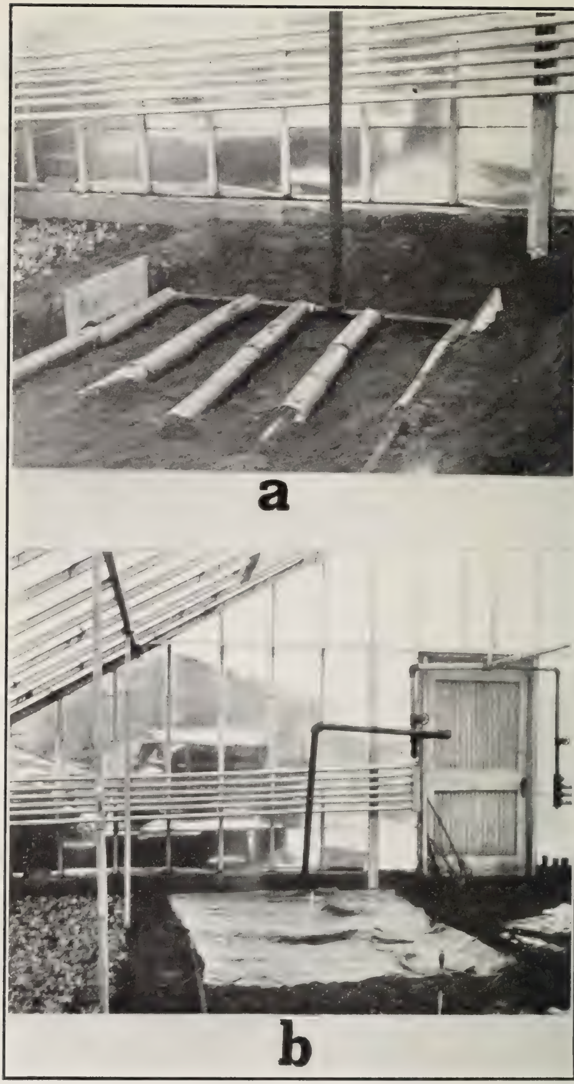

Fig. 6.

a. Steam sterilization apparatus, *b*. bed ready to be sterilized, showing steam connection and burlap covering.

reduced to three-fourths inch, then to one-half inch, then to three-eighths inch. The pegs are six inches long, and are placed eight inches apart, and consist of one-fourth inch pipe pounded together at the lower end. The steam escapes through a three-sixteenths inch hole at the lower wedge-like end of the pipe. The advantage of this apparatus is that it can be made to fit any bed. At 90 to 100 pounds pressure, more steam will naturally pass through the pipes than at thirty to forty pounds pressure. During the operation, a canvas cover laid on the beds will prevent the rapid escape of steam.

The Tile Method. This system is at its best when the steam pressure is low, at 25 to 30 pounds. With higher pressures the steam will blow out between the tiles. With this method, therefore, the soil should be sterilized for a longer period of time, from two to four hours, depending on the depth of tile and on soil conditions. Usually the tiles are not laid over one foot deep and from two to three feet apart. The joints of the pipes should be well matched.

Hot Water Sterilization. Numerous greenhouse men seem to prefer the use of hot water as a soil sterilizer to any other method here mentioned. Mr. Wm. L. Doran of the Massachusetts Experiment Station, who has made considerable study of this method, writes as follows:

"The soil should be thoroughly dry in the beginning so that it will take up the maximum amount of water. Before treatment, it is spaded over to

a depth of one foot to insure an open, porous condition. The water is heated in an ordinary boiler such as is used for heating the greenhouse, no extra equipment being needed. It is moved by a small pump operated by a motor and gasoline engine of a small horse power. The water comes out under forty pounds pressure, which insures considerable penetration into the soil. It is piped from the boiler through the center of the greenhouse in 1½-inch iron pipes. Most growers take the water from the bottom of the boiler rather than from the top, the object being to keep the temperature high but to avoid the steam which is objectionable. A thermometer is screwed into the main outlet pipe and is read frequently; the temperature should be above 201 degrees F., but if it goes much above 215 degrees F. the outlet pipe spits steam and is difficult and dangerous to use. To this iron pipe in the center of the house is attached a one-inch rubber hose fifty feet in length. This hose is replaced annually to decrease the danger of blow-outs and burns. Most growers sterilize once a year, some twice. The rubber hose is attached at the other end to a Y joint which is in the middle of a five-foot iron pipe one inch in diameter. The upper half of this pipe is plugged at both ends, serving simply as a handle, and from the lower half the water is delivered to the soil. A few feet back of this exhaust pipe the rubber hose is wrapped with burlap so that it may be carried over the shoulder of the workman. Some

Fig. 7. Effect of Soil Sterilization.

a. To left, sterilized soil planted in sweet peas, to right Rhizoctonia sick soil unsterilized and where seed failed to germinate. *b*. To left, sterilized soil planted in sweet peas, to right, Fusarium sick soil unsterilized, where seed failed to germinate.

growers shove the iron pipe down into the soil six inches; others hold it above the surface of the soil. The water penetrates equally well either way, because the soil is in a loose condition and the water goes out under pressure. There are no figures as to the exact amount of water per cubic foot of bed surface, but hot water is applied until it stands on the surface of the soil in pools and will no longer penetrate. The exact amount will, of course, vary with the physical condition of the soil and its relative dryness. The greenhouse men do not practice covering the soil with anything to hold in the heat. Out of doors, however, a cover would be desirable because of wind currents. Three or four days after treatment, the soil is cool enough and dry enough to plant."

It will require about two days for five men to treat a house 275 feet by 34 feet.

Roasting or Pan Firing. By this method, the soil to be sterilized is removed from the bed and placed in a pan, over a hot fire. After roasting, the soil is returned to the bed and more of it sterilized. This method is too slow and has the disadvantage, besides, of destroying the humus in the soil. The advantage of steam sterilization and of the "fire" methods lies in the destruction of all weed seed, together with the fungi which cause damping-off (fig. 7, a and b.).

A New Method of Steam Sterilization for Controlling Nematodes*

It has been our common experience, when attempting to control nematodes by steam sterilization of the soil, that very frequently one is unable to secure sufficient steam pressure satisfactorily to use the common harrow-type of sterilizer, the inverted pan or any modification of these types. When the steam pressure is only 50 to 60 pounds or less at the boiler, and where it becomes necessary to carry this a considerable distance in the greenhouse, condensation takes place, and as a result these sterilizers cause puddling of the soil and otherwise inefficient work. In our experiments, all modified types of steam sterilizers which originated from those already mentioned were equally unsatisfactory; therefore, a method which could utilize a low steam pressure and still do good work without injury to the soil, seemed urgent.

The method to be described herewith was used in a span of fifteen greenhouses, which had the soil badly infected with nematodes. For two successive seasons previous to the treatment of the soil, the entire crops of tomatoes and cucumbers were a total loss. After unsuccessfully trying out all styles of steam sterilizers, the device herein described was devised and proved successful.

It should be remembered where 80 pounds or

*By L. E. Melchers, Kansas State Agricultural Experiment Station.

more pressure is obtainable, the aforementioned kinds of apparatus may give very good results, but where the pressure is less, as in many cases in steam heated plants, they are not satisfactory.

The necessary equipment for this new device consists of two 2 x 4's cut at suitable lengths, a few boards either the entire length or half the length of the width of the greenhouse, canvas, burlap, sacking or tarpaulin. This method has been devised purposely for greenhouses growing vegetables on the ground, although modifications of this method could be made to suit other conditions.

The first operation in carrying out the work consists of digging a pit at one extremity of the house to the depth that one wishes the soil sterilized. The width and length depend somewhat upon the width of the greenhouse. In our work the pits were dug 12 inches deep, 6 to 8 feet wide and 10 to 15 feet long. Two 2 x 4's are laid on edge in the bottom of the pit. These pieces should be the length of the pit and placed about 6 to 12 inches from the sides of the pit. One or two leads of steam pipes with T outlets in the center and at the ends of the pipes should be laid in between these two stringers (2 x 4's). The pipes can best be run in from the ends of the pits. It has been found better to let the steam out in large quantities and not through perforated pipes. Pieces of 2 x 4's are then laid across these two stringers and should be long enough to reach across the width of the pit. Quite a large number are necessary to form a kind of platform. About a quarter of an inch

should be left between the 2 x 4 cross pieces to allow for the ascent of the steam (fig. 8, a, b, c.).

When the bottom has been laid, the soil which was removed can be thrown onto the platform. Boards should be staked around the sides of the platform to retain the soil. This forms a kind of wagon box. The steam can then be turned on, thermometers placed in the soil and the entire pit covered with any suitable covering to retain the heat.

Since steam rises, this method is much more satisfactory than where it becomes necessary to force the steam downward. There is no puddling of soil, even at the lower pressures, and 212 degrees F. and higher temperature can be obtained when sterilizing 12 inches of soil. It should be remembered that a few inches of soil below the wooden platform is likewise sterilized in this process. The skeleton platform is easily removed by means of an iron bar with a hook at the end for catching hold of the 2 x 4's and jerking them from underneath the soil. When the framework has again been set and the steam pipes adjusted in place, the platform is ready for the second batch of soil, which is dug immediately adjoining the soil which was just sterilized. In order to avoid extra labor, it becomes necessary to have one pit already dug just ahead of the bed being sterilized, so when the 2 x 4's are removed they can be laid immediately in the pit which is ready for them. This is accomplished by erecting the second bed on top of the first one, i.e., on top of the soil just sterilized.

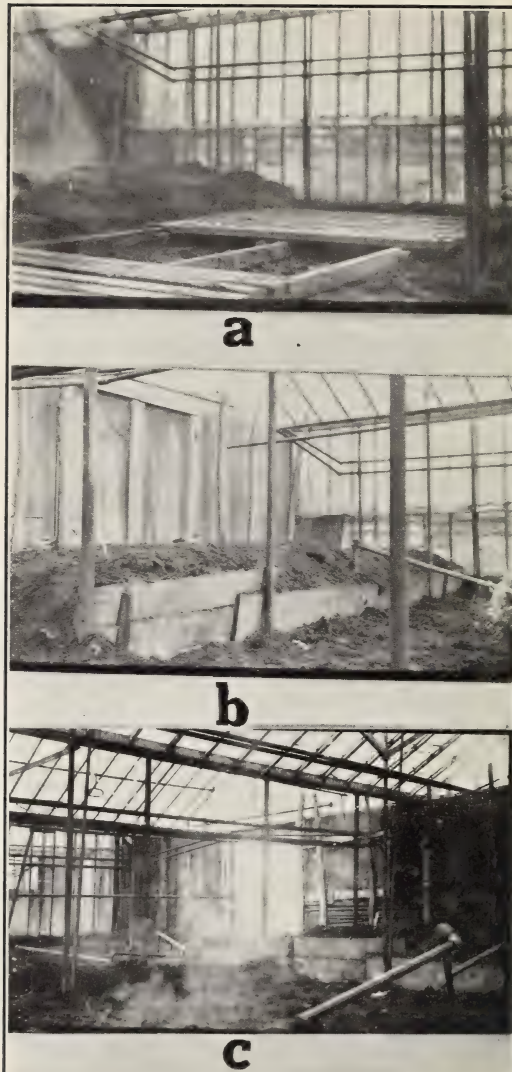

Fig. 8. Melcher's Soil Sterilizer.

a. The 2 x 4 bottom laid and ready for the soil, *b*. bed ready for steaming, *c*. steaming the soil in two beds running the width of the greenhouse.

When the second bed is ready for sterilization (*it is directly on top of the one first sterilized*), one has a pit already dug to set the framework in for the third batch, and from hence on, a pit will always be in readiness for the framework. It will be seen by this process and by such procedure that it becomes necessary to return one batch of sterilized soil to the opposite end of the greenhouse, after the whole house has been sterilized. This is the second batch, which was sterilized and sets on top of the first. This cannot be avoided, but the soil can easily be carted back by means of wheelbarrows.

Many greenhouses are irregularly constructed, with uprights and other obstructions more or less promiscuously scattered; therefore, the pan method is often difficult to use and it is less easy with the other unadjustable apparatus, but with the method just described these obstructions are much less serious, since they can be allowed to come in any part of the bed without hindrance to sterilization.

There is a little more expense connected with this method, on account of extra labor which is necessary, but this method is not being advocated as a superior way of steaming the soil, but rather to do the work where situations arise that cannot be handled otherwise.

Effect of Soil Sterilization on Seed Germination. The main object in sterilizing soils is to destroy the harmful fungus flora. Of all the methods here recommended, steaming is the most effective. Not all soils, however, are alike benefited by this treat-

ment. With lettuce seed, for instance, there is a higher per cent. of germination usually obtained in the sterilized soil. With tomatoes, however, germination is retarded under similar soil treatment. On the average, germination is favored by soil sterilization. This is well shown in Table 2.*

TABLE 2

Kind of Seed	Total Number of Seed Tested	Number Germinated in		Per Cent. Gain or Loss
		Sterilized Soil	Unsterilized Soil	
Radish	600	159	81	41
Tomato	600	93	110	13
Cucumber	600	281	187	33
Lettuce	600	26	10	61
Tomato	600	37	33	10
Onion	400	48	31	35
Mustard	400	84	32	61
Turnip	400	105	37	64
Onion	200	57	32	43
Lettuce	200	87	26	70

Effect of Soil Sterilization on Plants. That soil sterilization is practicable cannot be doubted. With some crops, the beneficial effect is especially marked. The Massachusetts Experiment Station † found a considerable increase in the production of violet blossoms as a result of soil sterilization. This is well shown in Table 3.

*From the Massachusetts Agr. Expt. Sta., 15th Rept.: 40-42, 1903.
† Massachusetts Agr. Expt. Sta., 12th Ann. Rept.: 165-167, 1900.

TABLE 3

Date	No. of Blossoms Picked		Percentage of Gain
	Unsterilized Soil	*Sterilized Soil*	
November	19	38	100
December	62	101	63
January	55	125	127
February	39	72	84
March	144	250	73
April	482	510	5
Total	801	1,096	...
Average	133	182	36

Not only was production of flowers increased in the sterilized soil, but there was also a decided decrease in leaf spots.

Changes in the Soil due to Sterilization. Various investigators have found that by steam heating, the physical, chemical, and physiological properties of a soil are more or less changed. Through chemical action there is an increase of soluble matter in some of the inorganic substances such as potash and phosphoric acid as well as in the organic matter. Ammonia is also formed by the reduction of nitrates to nitrites and by the decomposition of organic compounds, large amounts of which are also made available for plant growth. This, then, would explain the reason of the stimulation of growth in sterilized soils. However, steamed soils may also contain injurious substances, which upon becoming soluble are harmful to plant growth and to the germination of certain seed. This seems especially the

case in steamed soils deficient in lime. The investigations of Schreiner and Lathrop* have shown that as a result of heating, dehydroxystearic acid is produced, and that this is harmful to plant growth. Heating soil produces both beneficial and harmful substances. The fertility is raised or lowered, depending on which of these predominates. The result, however, is influenced by the crop, the fertilizer used, and the amount of lime applied. Coleman † has found that intermittent sterilization by means of dry heat at 82 degrees C. for five successive days in moist soil produced but very slight chemical changes. But this slow method is not very popular with the grower. Since, however, sterilized soils lose their harmful substances by standing, the treatment of the soil during the summer months, when there is no crop in the greenhouse, will obviate the main difficulty.

Other Methods of Controlling Damping Off. Damping off may be largely controlled by careful cultural conditions. Unless the soil of the seed bed has been sterilized, it is unwise to use the same soil in the beds where damping off has occurred previously. Thick sowing, too, should be avoided. In Table 4, Johnson ‡ presents some interesting data, showing the effect of thick sowing on damping off.

*Schreiner, O., and Lathrop, E. C., U. S. Dept. of Agr., Bur. of Soils, Bul. 89: 7-37, 1912.

† Coleman, D. A., et al., Soil Science: 259-274, 1916.

‡ Johnson, James, Wisconsin Agr. Expt. Sta., Research Bul. 31: 31-61, 1914.

TABLE 4

Flat Number	Weight of Seed Sown		Plants Diseased
	Per Flat	Per 100 Square Feet	
	Grams	Ounces	Per Cent.
1	0.1	0.16	0
2	0.2	0.33	0
3	0.3	0.49	8
4	0.4	0.66	15
5	0.5	0.83	35
6	0.6	0.99	75
7	0.7	1.16	80
8	0.8	1.33	80
9	0.9	1.49	92
10	1.0	1.60	96

Certain soils are especially favorable to damping off. Soils which contain a higher percentage of unrotted vegetable matter, and those which are hard to drain need special attention. Great care should be taken to keep the seed bed at the right temperature. The latter cannot be guessed at by personal sensation. It should be accurately determined by thermometers placed in the bed at suitable distances. It should also be remembered that any covering cloth or sash will exclude light and air. Every precaution should, therefore, be taken to prevent the seedlings from becoming "drawn," for in that condition they are most susceptible to damping off. The safest plan is to keep the temperature a trifle lower than is generally required, and to allow as much ventilation as possible. Very often damping off starts only in one corner of the bed. To check the rapid spread of the disease, the infected area

may be removed. Spraying the seedlings with various fungicides in a bed where damping off has become well established will be of little help.

Control of Insect-Infested Soil. Spraying the soil will be of little value in the control of underground insect pests. Fortunately, however, there are other means of dealing with them. All insect pests may, of course, be controlled by steaming the soil in the benches.

Cut worms may be controlled by the use of a poisoned bran made as follows: To three ounces of molasses add one gallon of water and sufficient bran to make a fairly stiffened mixture. To this add a teaspoonful of Paris green or arsenic and stir well into a paste. A heaping teaspoonful of the mixture is scattered here and there over the infested bed. The cut worms will be attracted to the sweetened bran and after eating it will die from the poison.

Summer Treatment of Greenhouse Soil

The greenhouse is rarely used the whole year round. During the summer the house is usually idle one or two months. This is especially true regarding truck crops, for at that time outdoor products put the greenhouse out of competition.

It is a common belief that if the soil is allowed to remain dry in the intense heat under glass during July or August all injurious insects, fungi and bacteria will be destroyed. To determine this point

Green and Green* have carried out some interesting experiments. They used beds which had been treated as follows: New soil, straw mulch, manure mulch, and a summer soil, sun-dried soil, in the greenhouse. The results of these experiments with tomatoes are shown in Table 5.

TABLE 5

Plot	1908	1909	1910	1911	1912	1913	*Average*
New soil	5.2	4.5	3.5	...	...	3.3	4.1
Straw mulch	4.9	3.2	3.1	...	...	2.5	3.4
Manure mulch	5.1	4.2	3.0	...	...	2.6	3.7
Dry	2.6	3.1	2.1	...	...	.9	2.1

It is seen from Table 5 that as far as tomatoes are concerned the new soil gave the best results. The manure mulch is second in productiveness. The effect of the dry mulch shows a rapid decline, and the dried soil showed the poorest yield. It must be added that in this soil the greatest amount of disease was present.

The result obtained with the soil treatment of tomatoes was found to be different from that with winter lettuce. This is more clearly brought out in Table 6 (see next page).

This table shows that the drying of the soil does not affect the lettuce crop to the same extent as it does tomatoes. Unlike most crops in the greenhouse, lettuce thrives best in old soil. On the other hand, cucumbers are as sensitive as the tomato to

*Green, W. J., and Green, S. N., Ohio Agr. Expt. Sta., Bul. 281: 53-68, 1915.

TABLE 6

Plot	1911	1911–12	1912	1912–13	*Average*
New soil	3.24	4.32	3.33	3.32	3.55
Straw mulch	3.06	3.01	2.85	3.00	2.98
Manure mulch	3.74	4.61	4.11	4.29	4.18
Dry	3.29	5.25	3.86	4.05	4.11

old, well manured soil in the greenhouse. This does not imply, therefore, that it is necessary to renew the soil every year for cucumbers or tomatoes. Soil sterilization, good drainage, and liming will tend to overcome the ill effect of old soils on these crops.

PART II

CULTURAL CONSIDERATIONS

CHAPTER 4

LIGHT IN ITS RELATION TO GREENHOUSE CULTURE

Of the many factors which are intimately interwoven with the growing of greenhouse crops, light is a very important one. Unfortunately, this subject has received scant attention. However, Dr. Stone* of the Massachusetts Agricultural Experiment Station has contributed greatly to our knowledge on this subject. It is apparent from his work that success with greenhouse crops goes hand in hand with a thorough understanding of the light requirements of plants. The problem of light has a direct bearing on the physiology and pathology of hothouse crops.

Physiological Relationship of Light

To realize the importance of this subject we must be aware that nearly ninety-five per cent. of the substances contained in the plant is derived from the atmosphere. These substances are manufactured through the action of light on the green matter (chlorophyll) located primarily in the leaves. This

* Stone, G. E., Massachusetts Agr. Expt. Sta. Bul. 144: 3-39, 1913.

process is known as photosynthesis. It consists of an intake and assimilation of carbonic acid by the plant, and a simultaneous liberation of oxygen. The carbonic acid breaks down and combines with the water to form the sugars and starch. The spectrum rays which are most concerned with the manufacture of starch are the orange and the red. The blue rays affect growth. Success with greenhouse plants depends largely on the intensity and the nature of the light rays which are permitted to penetrate through the glass. At best, these rays differ materially from the normal sunlight.

Contrary to general belief, plants make most growth at night or in the dark. On the other hand, photosynthesis takes place during the daytime and under the direct influence of light. While light does not favor growth, it assists in the development of supportive tissue which enables the plant to resist attacks of various diseases. The lack of a proper amount of light in the greenhouse causes the plants to possess little or no resistance to disease. This is especially true in the winter months. However, while insufficient light is conducive to disease, an excess of it, such as occurs in the summer months, is also detrimental to plant health in the hothouse. In that case, shading the glass becomes necessary. Moreover, there are numerous hothouse plants, such as palms for instance, which naturally require less light. On the other hand, lettuce, tomatoes, cucumbers, roses or carnations require more light in the

winter months than the ordinary hothouse is able to furnish.

Pathological Relationship of Light

While it is true that plants grow in the dark, they must have light to thrive. The growth made in darkness exclusively is of a soft nature. The long, whitish, slender sprouts of potato kept in the dark are a good illustration. Numerous diseases of plants grown under glass may undoubtedly be traced to improper light conditions. Cucumbers, for instance, when grown in poorly lighted houses, become slender, producing elongated petioles and stunted leaves with little green color in them. Such plants, too, are soft, and possess little of the solid or resistant tissue. Poor light also makes cucumbers, as well as most other hothouse plants, susceptible to mildew, blight and leaf spots. Poor light and wet soils are responsible for the burning of the foliage of hothouse plants under fumigation. Too much light often affects the transpiration of plants and causes them to wilt unduly. Blossom end rot of tomatoes under glass is more severe under bright light than under partial shading. No fixed rules can be given as to the light requirements of greenhouse crops. Until more definite knowledge is obtained on this important subject, the greenhouse manager will of course depend on his common sense, observations and experience to guide him.

Construction and Management of Hothouses as Affected by Light Conditions

From the previous discussion, it is now evident that to improve light conditions indoors will tend to produce normal growth and to hasten maturity. The greater the photosynthesis, the more rapid the assimilation of plant food, hence the quicker the growth. An increased amount of heat can never replace the normal effect of an increase of light for those crops which most require it. Many growers, especially those who possess poorly constructed houses, often attempt to substitute heat for light in forcing. The result is generally a failure, because diseases of all sorts find the tender weak plants an easy prey to their attacks. The modern greenhouse man is partly solving the light problem by constructing larger houses and using larger glass. As a result of this, more air space and more uniform moisture distribution is assured. The double-thick, third quality glass, used in previous years, is now being replaced by a good grade of double-thick, second quality glass. Improvements are also being introduced in the roof angles, for these, too, mean added and better light. The more closely the angle of the roof coincides with the right angle cast by the sun's rays, the greater the amount of light that may reach the indoor plants. In the old form of houses, many of which are still in existence, the glass used was from two to seven inches long and two to five inches wide, and was often lapped more

than an inch. This system practically excluded fifty per cent. of the light. The modern house uses glass varying in dimensions from 16 inches by 24 inches, 20 inches by 30 inches to 24 inches by 24 inches. With the use of the larger glass, the diminished lapping results in a considerable saving of light. To prevent breakage of the larger glass a house must, of course, be solidly built and well purlined.

The location of the house, too, influences the amount of light taken in. Houses located north and south are benefited by the morning light only, whereas those running west receive only the afternoon light. The ideal location from the light viewpoint would be to set the house on a line running 20 to 25 degrees north of east.

Houses with greater roof angles naturally receive more light. It is also a well conceded fact that light will pass through a transparent object more easily if it is placed at right angles to the light rays. This fact is not often taken advantage of by greenhouse builders. However, it cannot be denied that the sunlight strikes the house at different angles during the day and likewise at different seasons of the year, thus producing considerable variation in the amount of light reflected. To obviate this, houses should be built with greater roof angles, a plan which will insure less reflection and thus allow a greater amount of light to penetrate. During January, for instance, when the normal sunlight is naturally less, glass placed at an angle of

60 degrees will absorb far more light than if placed at angles of 10 or 30 degrees.

It has been the general belief that the light in the hothouse was greatest nearest to the glass. Experience has disproved this. Modern houses are built larger, which means a greater distance between glass and plants.

Effects of Various Colored Lights

That plants require light for their normal development and for the proper performance of their function no one doubts. Crops grown outdoors naturally receive their light from the sun's rays. Plants within the greenhouse do not always receive the rays of the sun in a normal way. As a result, the health of these plants may often be impaired, or the quality of the product greatly affected. The researches of Flammarion* on this subject are of particular interest to the greenhouse man.

Temperature Influenced by the Color of the Glass

Flammarion has shown that temperature is affected by the color of the glass. Houses differentiated by the following sorts of colored glass were tried: blue, approaching closely to violet; red traversed by a little orange; green and ordinary white glass. These four houses were placed side by side

* Flammarion, Camille. Experiment Station Record 10: 103-114, 1898.

and equal conditions of care and culture were observed in all of them, approaching natural conditions as nearly as possible. The temperatures in these houses are given in Table 7.

TABLE 7

Time of day	*White*	*Red*	*Green*	*Blue*
	Degrees	*Degrees*	*Degrees*	*Degrees*
7:30 A.M.	32.0	31.0	30.7	29.5
8:30 A.M.	40.0	39.5	37.0	35.0
10:30 A.M.	49.0	46.0	41.5	40.0
12:30 P.M.	42.0	40.0	39.0	38.0
2:30 P.M.	41.0	40.5	40.3	40.2
4:30 P.M.	30.0	30.0	30.0	30.0

It is evident that the ability of the glass to absorb the sun's rays determines the heat in the hothouses. All rays are able to pass through white glass, which explains why the highest temperatures were found in this house. The lowest temperatures were found in the blue house, blue having the greatest absorbing power. It is striking that the temperature was apparently the same in all the hothouses during the cloudy weather and when the sun's rays did not penetrate directly.

PLANT GROWTH INFLUENCED BY THE COLOR OF THE GLASS

Experiments on sensitive plants showed the following results: Plants placed in a red house de-

veloped a height fifteen times as great as that in the blue house, where practically no growth was made. The red light in this case acted as a fertilizer. Moreover, the sensitiveness of the plants grown in the red house had increased considerably. The slightest movement or breath was sufficient to cause the leaflets to close, or the pedicels to droop. The sensitiveness diminished under the white or green color, while under the blue glass the sensitiveness was almost lost. The plants in the red house were first to bloom. In the white house they increased in stockiness and in vigor, but did not seem to increase in height. The plants in the house with the red glass possessed foliage which was lighter than those grown in the white house, while under the blue glass the foliage was much darker. After three months the height of the plants in the different houses was as shown in Table 8.

TABLE 8

Date	*Red*	*White*	*Green*	*Blue*
	Meter	*Meter*	*Meter*	*Meter*
June 13	0.030	0.030	0.030	0.030
July 22	0.230	0.120	0.080	0.035
August 16	0.380	0.240	0.100	0.035
August 30	0.470	0.270	0.100	0.035
October 12	0.500	0.380	0.100	0.035

From the preceding table it is seen that the plants in the hothouse with the red glass attained

greater height and exhibited more sensitiveness than those in the white house. The sensitive plants in the green hothouse made a little headway at first and then came to a standstill. In the hothouse with the blue glass practically no headway was made. In comparing the weight of the plants in the various hothouses with that of the height as previously mentioned, the results will be found to be different. This is clearly seen in Table 9.

TABLE 9

Hothouse	*Weight of Stems and Leaves*	*Weight of Average Leaf*	*Diameter of Stem*
	Grams	*Grams*	*Mm.*
White................	8.400	0.600	3.0
Red..................	4.600	0.250	2.0
Green................	0.300	0.150	1.5
Blue.................	0.150	0.095	1.0

It is very curious to find that the plants in the red hothouse, although the highest, were not the heaviest. The weight was almost double in the white hothouse, although in height the plants did not compare to those in the red hothouse.

Experiments on lettuce, similar to those on the sensitive plants, yielded like results. Lettuce grown in the white hothouse produced large thick leaves with well rounded heads, in fact the plants here did not differ from those grown in the open. Lettuce grown in the red house was drawn, its leaves

long, straight, blanched and drooping. Those grown in the hothouse with green glass made a slight growth, but the leaves were more curled than those in the red house. In the blue hothouse, the lettuce plants added only a few leaves, without increasing the height attained in the first two weeks (fig. 9, i-j.).

Experiments on peas and beans yielded similar results. In both plants the normal and most vigorous growth was found to occur in the white hothouse. The plants in the red hothouse were taller but thinner, while in the blue hothouse the minimum of growth occurred. The beans bloomed and fruited equally well in the white and in the red hothouses. In the green and in the blue houses the plants soon died. With the peas, blooming and fruiting seemed to be normal both in the white and in the red hothouses. In the house with the green glass, the peas remained in bloom for three weeks, but did not fruit. In the blue house, the peas failed to bloom altogether.

Experiments with ornamental plants, such as Coleus, yielded similar results. The Coleus in the white hothouse produced a normal well developed plant. In the red house there was an increase in height with a decrease in foliage. In the green and blue hothouses there was very little development (fig. 9, a-h.).

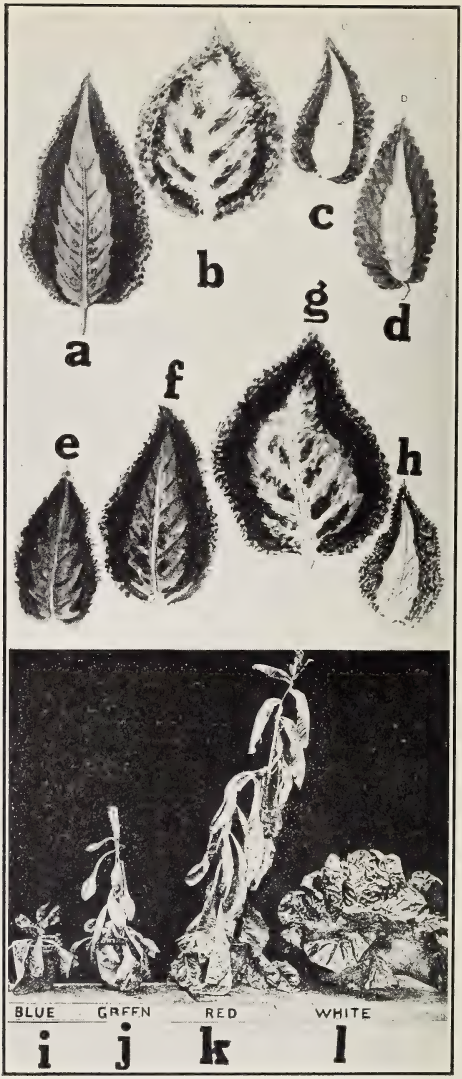

Fig. 9. Action of Different Light Rays on Coleus and on Lettuce.

a. Full radiation, *b.* red rays, *c.* green rays, *d.* blue rays, *e.* open air, *f.* subdued light, *g.* diffused light, *h.* very dim light, *i.* blue light, *j.* green light, *k.* red light, *l.* white light (*a-l* after Flammarion).

Root Development Influenced by the Color of the Glass

It has already been seen that different rays of the solar spectrum may modify the parts of the plant above ground. The same effects may also appear in the root system of such plants. The root system is considerably smaller in the red hothouse than it is in the white hothouse. In the hothouse with green glass, the root system is very poorly developed, while in the blue there is almost no root system.

Anatomy of the Plant as Influenced by Different Rays of Light

As we have seen, different rays of light are capable of influencing the growth of plants. The same is also true of the structure of plants. Flammarion has found that sensitive plants, for instance, when grown in a white hothouse, possess a thicker epidermis, more numerous wood fibers in the stem, and the pith was much less developed than was the case with similar plants grown in red, green or blue hothouses.

Effect of White and Colored Light on Transpiration

The effect of various lights on transpiration is shown in Table 10.

TABLE 10

Color	*Weight of Leaf*	*Weight of Transpired Water*	*Water Transpired per Gram of Leaf*
	Grams	*Grams*	*Grams*
Red	0.135	0.208	1.540
Yellow	0.102	0.230	2.254
Green with some yellow rays	0.095	0.065	0.682
Violet	0.080	0.024	0.302

It is thus seen that the greatest transpiration takes place under the yellow light, and the least under the violet.

EFFECT OF VARIOUS LIGHT RAYS ON THE COLOR OF PLANTS

It is well known that the green color of leaves which is due to chlorophyll can only be produced in the light. Other plant colors such as red, yellow, blue, may be due to the presence of colored pigments, or to color in the cell sap itself.

That light and not temperature is capable of changing the colors in plants has been proven by the investigations of Flammarion. He found that lilac blossoms in a white hothouse became pink, and in red, green and blue hothouses the blossoms became white. If the lilac blossoms already colored are placed under a dark bell jar, they will turn from pale blue to clear red violet. This change of color

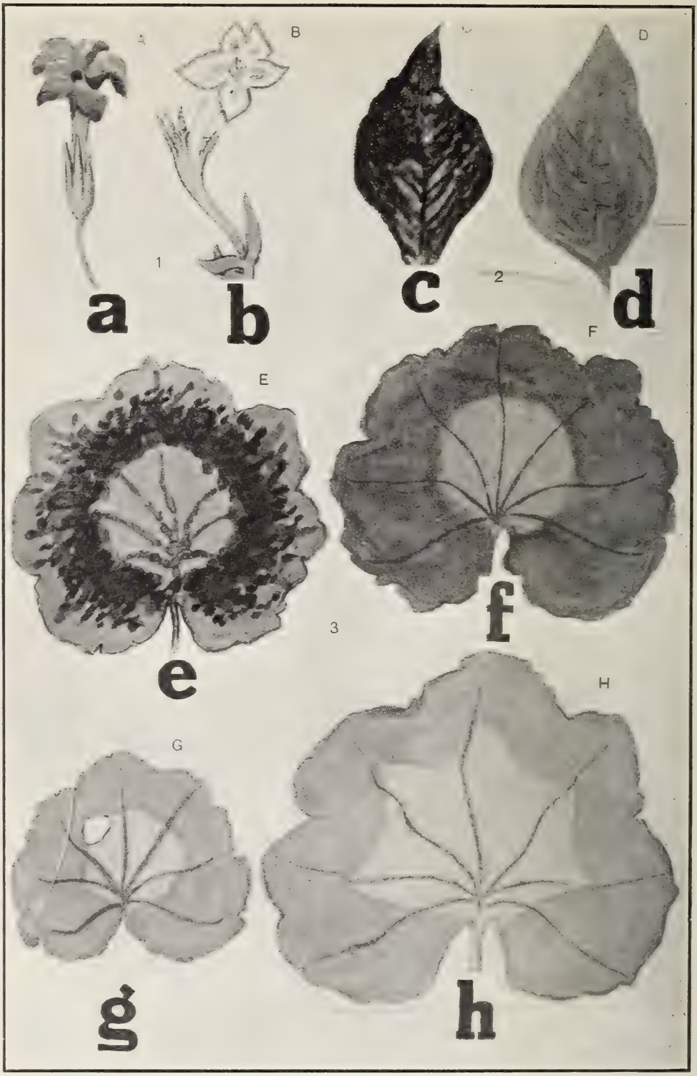

Fig. 10. Action of Different Light Rays on the Color of Plants.

a. Red flowered Crassula in sunlight, *b.* same in darkness, *c. Alternanthera amoena* full radiation, *d.* same under red rays, *e.* geranium leaves full radiation, *f.* same under blue rays, *g.* green rays, *h.* red rays (*a-h,* after Flammarion).

is not due to temperature. It is due solely to the effect of various light rays. Lilac blossoms, for instance, if enclosed in a dark chamber will become discolored, irrespective of surrounding temperatures.

Coleus plants grown in a white hothouse will produce leaves with the normal amount of red color and pigmentation. In a red hothouse, the red pigment of the Coleus decreases, the leaves are more spread, and their form is changed. Coleus grown under green-colored glass produces leaves of small sizes, the pigments almost disappear, and give place to a yellow coloration. The same is true also when Coleus is grown under blue glass. In this case, however, the red pigments disappear almost completely (fig. 9, a-d.). In substantiation of the fact that light is capable of transforming plants, Flammarion refers us to the following experiment: Coleus plants may gradually be transformed when grown under a slightly diffused light through a garden frame, in diffused light, and in still weaker light. The plants grown in the open are of course normal. The most curious transformation occurs in the diffused light. Here the leaves enlarge considerably and the red pigments diminish in the center. Under a weak light the Coleus leaves become stunted, and the color changes from poppy red with a dark edge to yellow with a light green edge (fig. 9, e-h.). Purple leaves of Alternanthera amena will become green under red glass. In the open, geranium leaves possess a reddish brown tone. This color changes under red, green or blue rays (fig. 10, a-h.).

These experiments seem to indicate that light is of itself able to modify plants.

Effect of Light on Disease Resistance

It has already been seen that light is an important factor in plant culture. It alone seems able to change the form of a plant as well as its color. Moreover, the resistance of a plant to a disease may be modified by light. Damping off, for instance, a prevalent disease in greenhouses, is more virulent on dark cloudy days, when the light in the hothouse is abnormal and weak. A temporary change in the normal functions of the metabolism of the plant occurs and is followed by a sudden lowering of vitality. The greenhouse man cannot overlook the importance of the light requirement of plants under glass. Experience has shown that white glass is the only one capable of furnishing the necessary light rays to the plant. Needless to say, that only the best quality should be secured, for economies in the quality of glass may not always be the wisest nor the cheapest in the end.

Electro-Culture

The field of greenhouse culture is a plastic one. Electricity is undoubtedly capable of influencing plant growth. The greenhouse man who is conscious of the possibilities of control in his plastic domain will not neglect this phase of plant culture.

Effect of Electric Light

It has always been a question whether growth under hothouse conditions could not be hastened by using artificial light at night. The work of Rane* has shown that such is the case.

The beneficial effect on lettuce seems to be especially marked for the Grand Rapids variety first, next for the Hanson and thirdly for the Tennis Ball, the only three varieties experimented on by Rane. The lettuce in the house lighted with electricity seemed more erect, vigorous, and the soil freer from damping off and rot-producing organisms. This is indeed an important consideration. Moreover, the lettuce in the electrically lighted house matured about twelve days earlier than that grown otherwise. Greenhouse spinach, like lettuce, seems also to be benefited by electric light at night. On the other hand, cauliflower reacts poorly to this treatment. Although the plants are taller, the quality of the head is of an inferior grade. Radishes develop more tops than roots. The practical-minded greenhouse man will use electric light at night to induce extra stimulation for those greenhouse crops that respond favorably to it. The cost of installing the system certainly cannot be considered as a real drawback. Electricity in these days may be obtained at a reasonable price. This is especially true of greenhouses situated near large

*Rane, F. W., West Virginia Agr. Expt. Sta. Bul. 37, Vol. 4, No. 1: 3-27, 1894.

cities. But more extensive investigations are needed to convince the grower of the practicability of the attempt.

Effect of Shading

It has been shown in the previous chapter that certain light rays, such as green or blue, are detrimental to plant growth. On the other hand, the normal sun rays from outdoors or as they come through white glass are most conducive to normal plant culture. The practical man, however, realizes that at certain times of the year, especially during the summer months, the white glass must be shaded to prevent an excess of sunlight. This is accomplished by whitewashing the glass. That this procedure is necessary no one can question. However, it must be admitted that the method itself is still a crude one, inasmuch as the various plants in the hothouse are subjected alike to the same amount of shading. Shantz* has shown that while a certain amount of shading is beneficial to plant growth, yet not all plants are benefited alike by this treatment.

Effect of Different Light Intensities on Plants

The work of Shantz distinctly shows that all plants do not tolerate the same amount of shading. To prove this he grew various crops in a bed cov-

* Shantz, H. LeRoy, U. S. Dept. Agr. Bur. Pl. Ind. Bul. 279: 7-29, 1913.

ered with cloths of different textures. The arrangement of the cloth and the amount of light penetrating it are shown in Table 11.

TABLE 11

Method of Determining the Effect of Different Light Intensities

Section of Bed.........	1	2	3	4	5	6
Cloth Used............	*Black Duck*	*Light Canvas Cloth (Black)*	*Chambray*	*Light Chambray*	*Voile*	*No Cover*
Fraction of normal light capable of passing through cloth.......	1/93 or n/93	1/15 or n/15	1/7 or n/7	1/5 or n/5	1/2 or n/2	1 or n

As an explanation to Table 11, in referring for instance to column marked 2, $n/15$, we mean the second section of the bed where light canvas cloth (black) was used for shading, and where the light capable of passing through was equivalent to 1/15 or $n/15$, *1* or n represents the normal. The same interpretation is given to the other sections of Table 11, all of which really correspond to the sections of the bed experimented with, it being remembered that *1* or n represents normal light.

Effect of Different Light Intensities on Lettuce

According to Shantz, lettuce could not grow in section 1 under $n/93$ illumination, as the seedlings died as soon as the reserve food material in the cotyledons was consumed. In section 2, $n/15$

illumination, growth was barely possible. The plants in this case were emaciated and worthless. It seems, therefore, evident that lettuce cannot stand shading where the light is reduced to $n/15$. The greatest amount of gain is made by lettuce when the intensity of the light ranges between $n/7$ and $n/5$. At this point the stimulation is greater than in those grown under normal light or even at $n/2$. In full light lettuce plants are smaller than in $n/7$ or $n/5$ light. In flavor, a very slight change only may be noticed between plants grown under full light and those receiving $n/2$ light. However, under $n/5$ illumination the strong taste seems to disappear entirely. When the light is reduced to $n/7$ the flavor seems to improve even more. Moreover, in this case the plants acquire the particular form of growth required by the market more consistently than do those that are produced in brighter light.

Effect of Different Light Intensities on Radish

Young radish seedlings seem capable of standing about 30 days under $n/93$ illumination. At the end of that time, however, they die. In $n/15$ light there is almost no growth. The best gains seem to be made under a light of $n/2$ or $n/5$. In this respect, the shade tolerance of the radish is somewhat similar to lettuce. However, the effect of shade is not noticeable in the flavor of the radish.

From the above evidence it is apparent that plant growth is assisted by shading, the degree of which

must be worked out for each specific crop. Ordinarily, under greenhouse conditions, shading is accomplished by means of whitewashing the glass of the hothouse. It would seem more desirable to use chambray, light chambray or voile cloth instead of whitewashing. The cloth could be installed on a system of rollers, so that when shading is necessary it could be spread out on the glass and when not needed it could be rolled up again. This would enable the greenhouse man to retain the full amount of normal light on cloudy days, an advantage which cannot be obtained when the glass is whitewashed. The substitution of cloth for whitewashing offers a good field of experimentation, both for the laboratory and for the practical man.

Heat Requirement

The heat requirement of indoor crops demands the closest attention and study. As is well known, no two crops require the same temperature for their maximum development and production. Moreover, the same plant requires different temperatures in its various stages of growth. To appreciate thoroughly the relationship of heat to plant life, we may liken the plant to a steam engine. With very slight steam pressure, the engine remains "dead," because it is not able to overcome the friction of its own parts and hence is capable of no work. With the proper amount of steam pressure, the engine is capable of a maximum amount of work.

However, if an excess of steam pressure is used, the engine under an excessive strain will break or explode. The same is true with plants. A low temperature may not suffice to awaken the active life processes. With increased temperature, the plant becomes capable of maximum activity. Temperature beyond the normal requirements causes it to suffer or even to die from weakness and disease.

The ideal development with forced plants is possible only if we consider the relationship of the soil temperature to that of the air. For instance, the burn of lettuce is brought about by rapid evaporation of moisture from the leaves at a time when the roots are unable to supply this excessive demand of water. If the soil is cold, or its temperature different from that of the house air, the roots will be unable to supply fast enough the water needed by the foliage. This will result in their collapse or burning, and the ruin of the lettuce crop. The proper temperature requirement for each crop will be taken up when we consider further the cultural requirements of each.

CHAPTER 5

MOISTURE AND WATER REQUIREMENTS

MOISTURE here means the humidity present in the hothouse atmosphere. The importance of this subject is as yet little appreciated by the practical man. The investigations of Blake* on the moisture requirements of roses point to the urgent need of similar experiments on other commercial hothouse crops.

In the greenhouse, temperature and humidity rank with food in their importance to the plants.

Effect of Humidity on Rose Foliage. Frequently when a greenhouse crop fails, the soil, the fertilizer or the water receives the burden of the blame. Little does it occur to us that the cause of the failure may be due to improper adjustment of humidity to temperature and watering. That each crop requires different humidity conditions is well conceded. The maidenhair fern, for instance, will not thrive in a house with a dry atmosphere, a condition which is ideal for other plants such as ornamental cacti. With roses a low humidity tends to reduce the size of the leaves, and the latter become "hard" and lose their flexibility. Again, vigorous, dark green foliage indicates a proper degree of humidity.

* Blake, M. A., New Jersey Agr. Expt. Sta. Bul. 277: 3-55, 1915.

Relation of Temperature and Humidity in the Greenhouse

The investigations of Blake show (Table 12) that the humidity decreases in direct proportion to an increase in temperature. The opposite occurs when the temperature is lowered.

Table 12

Humidity as Affected by Temperature

Date, 1914	*Outdoor Weather Conditions*	*Time of Day*	*Ventilation*	*Heat*	*Temperature in House*	*Humidity*
Feb. 11	Fair.............	11:00 A.M.	Yes	On	70	72
Feb. 11	Fair.............	10:30 A.M.	Yes	Off	64	90
Feb. 12	Fair.............	1:30 P.M.	None	On	62	72
Feb. 12	Fair.............	4:00 P.M.	None	On	64	70
Feb. 13	Fair, cold.........	11:30 A.M.	None	Off	68	80
Feb. 13	Fair, cold.........	3:30 P.M.	None	On	65	75
Feb. 14	Fair.............	2:15 P.M.	None	Off	71	82
Feb. 14	Fair.............	5:00 P.M.	None	On	61	69
Feb. 16	Fair.............	2:00 P.M.	Yes	Off	65	95
Feb. 16	Fair.............	5:00 P.M.	None	On	63	79
Feb. 17	Rain.............	8:00 A.M.	None	On	60	89
Feb. 17	Rain.............	1:00 P.M.	Yes	Off	67	95
Feb. 18	Snow and rain....	8:00 A.M.	None	Off	67	90
Feb. 18	Snow and rain....	3:45 P.M.	None	Off	64	86
Feb. 20	Fair.............	11:00 A.M.	Yes	Off	67	90
Feb. 20	Fair.............	4:30 P.M.	None	On	64	85
Feb. 21	Fair.............	8:00 A.M.	None	On	71	65
Feb. 21	Fair.............	1:00 P.M.	Yes	Off	72	78

From Table 12 it is evident that heat lowers the humidity. It is also to be noted that the decrease in humidity is rapid on bright days even when most cold. It is to be further noted that not only the heat, but the ventilation of the house during the day when the heat is turned on in the pipes, tends to reduce the humidity still further. Rose growers, for instance, are aware that at the approach of spring the plants suddenly improve greatly. This is generally attributed to longer and brighter days. However, according to Blake, this change is due to an increase in humidity in the hothouse due to the shutting off of the heat in the pipes.

Effect of Humidity on Greenhouse Crops

For further information on this subject, we have to refer again to the researches of Blake. He finds that the American Beauty rose, for instance, as a result of insufficient humidity fails to produce new shoots from the base of the plant. Moreover, the foliage, except at the tips of the growing shoots, becomes hardened and toughened. The older leaves turn yellowish and fall off prematurely, leaving bare stalks. As a result of this the younger and smaller rootlets die out. Blake also found that a high humidity tends to increase the size of the foliage, and the flowers seem to be likewise favorably affected. With low humidity the leaves of small rose plants wilt on bright days, even though the soil is kept moist. Frequently the leaves turn black,

which is really a form of sunburn. This is undoubtedly caused by the dryness of the atmosphere in which the moisture in the leaves is given off faster than the roots can supply it.

Humidity as Affected by Walks in the House

There seems to be a tendency among modern greenhouse men to build benches and sidewalks of cement. While this may be very desirable from a hygienic viewpoint, it is objectionable for the maintenance of the proper degree of humidity. It is extremely difficult to raise the humidity of a house with cement walks. This is true even when water is applied to the walks and sprinkled on the plants. In houses devoted to roses and similar plants, where it is desirable to maintain a humidity of at least 75 per cent., cement walks become quite objectionable; cinder walks are to be recommended instead. Cement walks may be readily transformed by covering them with a layer of six inches of cinders. This covering will make it possible to maintain a higher and more uniform humidity.

Humidity is also an important factor in the heating of glass houses. The greater the humidity the greater is the evaporation of moisture, and the greater is the amount of heat required to maintain a uniform temperature. Without proper attention to these conditions, the hothouse crop may be doomed to failure.

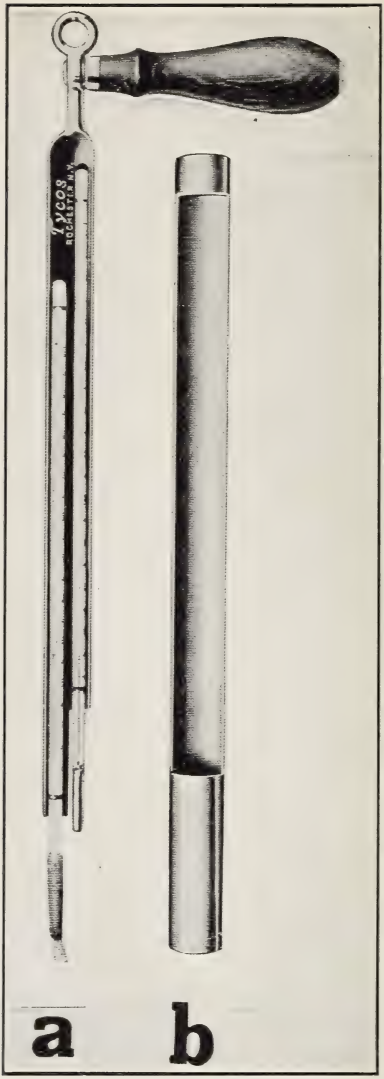

FIG. 11.

a. Sling psychrometer, an instrument used to determine the relative humidity in the air, *b.* case cover.

Humidity Determination in the Greenhouse

Perhaps the quickest and safest way of determining the relative humidity of the air in the hothouse is by means of a sling psychrometer (fig. 11.). This instrument is very simple in design. It consists of a wet and dry bulb thermometer attached to a wooden or metal support. The handle arrangement permits the instrument to be whirled in the air while taking the reading. The wet bulb thermometer is covered with muslin and is thoroughly moistened by being plunged into a cup of water which should be of the same temperature as that of the air of the hothouse.

Method of Determining Humidity

After wetting the muslin of the wet bulb thermometer, the instrument is whirled steadily for a few seconds and the reading of the wet bulb thermometer noted. This whirling is repeated several times, until the reading of the wet bulb thermometer is constant. At this stage, the difference of temperature between the wet and dry thermometers is recorded. After this difference has been obtained, we turn to Table 13 to get the exact reading of the relative humidity of the hothouse air. To make this clear to the reader, let us take a specific example. Suppose that the reading of the wet bulb thermometer was 64 degrees, and that of the dry bulb thermometer 62 degrees. This, then, will give us

a difference of two degrees between the wet and the dry bulb thermometer. Let us now refer to the table under the column *Dry bulb thermometer degrees*, where it is marked 62 degrees. Read across Table 13 under the column *depression of wet bulb thermometer in degrees* until the column indicates a difference of two degrees. In this case it is the fourth column. The resultant figure, 89, will be the relative humidity of the hothouse air. In other words, a temperature of 62 degrees of the dry bulb thermometer with a difference of two degrees of the wet bulb thermometer will give a reading of 89 relative humidity of the air. In like manner, and by referring to Table 13, which should be hung up at a convenient place in the hothouse, the relative humidity of the house may be obtained. There are other simpler instruments by means of which the reading of the relative humidity may be obtained directly without the use of tables. The Mithoff hygrometer, for instance, is a type of such an instrument. However, they may readily get out of commission, and thus become unreliable.

Watering

The importance of water for greenhouse plants cannot be too emphatically stated. It has been truly said that "he who does not know how to water plants does not know how to grow them." Water is essential to plant life. It has been intimated that some crops evaporate from the leaves an amount

TABLE 13

Relative Humidity, Per Cent.—Fahrenheit Temperatures. Pressure 30.0 Inches

Dry Bulb Thermometer Degrees	Depression of Wet Bulb													
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
50......	96	93	90	87	83	80	77	74	71	67	64	61	58	55
51......	97	94	90	87	84	81	78	75	71	68	65	62	59	56
52......	97	94	90	87	84	81	78	75	72	69	66	63	60	57
53......	97	94	90	87	84	81	78	75	72	69	66	63	61	58
54......	97	94	91	88	85	82	79	76	73	70	67	64	61	59
55......	97	94	91	88	85	82	79	76	73	70	68	65	62	59
56......	97	94	91	88	85	82	79	76	73	71	68	65	63	60
57......	97	94	91	88	85	82	80	77	74	71	69	66	63	61
58......	97	94	91	88	85	83	80	77	74	72	69	66	64	61
59......	97	94	91	89	86	83	80	78	75	72	70	67	65	62
60......	97	94	91	89	86	83	81	78	75	73	70	68	65	63
61......	97	94	92	89	86	84	81	78	76	73	71	68	65	63
62......	97	94	92	89	86	84	81	79	76	74	71	69	66	64
63......	97	95	92	89	87	84	82	79	77	74	71	69	67	64
64......	97	95	92	90	87	84	82	79	77	74	72	70	67	65
65......	97	95	92	90	87	85	82	80	77	75	72	70	68	66
66......	97	95	92	90	87	85	82	80	78	75	73	71	68	66
67......	97	95	92	90	87	85	83	80	78	75	73	71	69	66
68......	97	95	92	90	88	85	83	80	78	76	74	71	69	67
69......	97	95	93	90	88	85	83	81	79	76	74	72	70	67
70......	98	95	93	90	88	86	83	81	79	77	74	72	70	68
71......	98	95	93	90	88	86	84	81	79	77	75	72	70	68
72......	98	95	93	91	88	86	84	82	79	77	75	73	71	69
73......	98	95	93	91	88	86	84	82	80	78	75	73	71	69
74......	98	95	93	91	89	86	84	82	80	78	76	74	71	69
75......	98	96	93	91	89	86	84	82	80	78	76	74	72	70
76......	98	96	93	91	89	87	84	82	80	78	76	74	72	70
77......	98	96	93	91	89	87	85	83	81	79	77	74	72	71
78......	98	96	93	91	89	87	85	83	81	79	77	75	73	71
79......	98	96	93	91	89	87	85	83	81	79	77	75	73	71
80......	98	96	94	91	89	87	85	83	81	79	77	75	74	72

Table 13 (continued)

Relative Humidity, Per Cent.—Fahrenheit Temperatures. Pressure 30.0 Inches

Thermometer in Degrees

7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5
52	49	46	43	41	38	35	32	29	27	24	21	18	16	13	10	8
53	50	47	45	42	39	36	34	31	28	26	23	20	17	15	12	9
54	51	49	46	43	40	37	35	32	29	27	24	22	19	17	14	11
55	52	50	47	44	41	39	36	33	31	28	26	23	20	18	16	13
56	53	50	48	45	42	40	37	35	32	29	27	24	22	20	17	15
57	54	51	49	46	43	41	38	36	33	31	28	26	23	21	19	16
57	55	52	50	47	44	42	39	37	34	32	30	27	25	22	20	18
58	55	53	50	48	45	43	40	38	35	33	31	28	26	24	22	19
59	56	54	51	49	46	44	41	39	37	34	32	30	27	25	23	21
59	57	55	52	49	47	45	42	40	38	35	33	31	29	26	24	22
60	58	55	53	50	48	46	43	41	39	37	34	32	30	28	26	23
61	58	56	54	51	49	47	44	42	40	38	35	33	31	29	27	25
61	59	57	54	52	50	47	45	43	41	39	36	34	32	30	28	26
62	60	57	55	53	50	48	46	44	42	40	37	35	33	31	29	27
63	60	58	56	53	51	49	47	45	43	41	38	36	34	32	30	28
63	61	59	56	54	52	50	48	46	44	41	39	37	35	33	31	29
64	61	59	57	55	53	51	48	46	44	42	40	38	36	34	32	30
64	62	60	58	56	53	51	49	47	45	43	41	39	37	35	33	31
65	62	60	58	56	54	52	50	48	46	44	42	40	38	36	34	32
65	63	61	59	57	55	53	51	49	47	45	43	41	39	37	35	33
66	64	61	59	57	55	53	51	49	48	46	44	42	40	38	36	34
66	64	62	60	58	56	54	52	50	48	46	45	43	41	39	37	35
67	65	63	61	59	57	55	53	51	49	47	45	43	42	40	38	36
67	65	63	61	59	57	55	53	51	50	48	46	44	42	40	39	37
67	65	63	61	60	58	56	54	52	50	48	47	45	43	41	39	38
68	66	64	62	60	58	56	54	53	51	49	47	45	44	42	40	39
68	66	64	62	61	59	57	55	53	51	50	48	46	44	43	41	39
69	67	65	63	61	59	57	56	54	52	50	48	47	45	43	42	40
69	67	65	63	62	60	58	56	54	53	51	49	47	46	44	43	41
69	68	66	64	62	60	58	57	55	53	51	50	48	46	45	43	42
70	68	66	64	62	61	59	57	55	54	52	50	49	47	45	44	42

TABLE 13 (continued)

Relative Humidity, Per Cent.—Fahrenheit Temperatures. Pressure 30.0 Inches

Dry Bulb Thermometer Degrees	Depression of Wet Bulb									
	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5
50	5	3	0	..	..	..	..	..	..	..
51	7	4	2	..	..	..	..	..	..	..
52	9	6	4	1	..	..	..	..	..	..
53	10	8	6	3	1	..	..	..	..	..
54	12	10	8	5	3	1	..	..	..	..
55	14	12	9	7	5	2	0	..	..	..
56	16	13	11	9	7	4	2	..	..	..
57	17	15	13	10	8	6	4	2	..	..
58	18	16	14	12	10	8	6	3	1	..
59	20	18	16	13	11	9	7	5	3	1
60	21	19	17	15	13	11	9	7	5	3
61	22	20	18	16	14	12	10	8	7	5
62	24	22	20	18	16	14	12	10	8	6
63	25	23	21	19	17	15	13	11	10	8
64	26	24	22	20	18	17	15	13	11	9
65	27	25	24	22	20	18	16	14	12	11
66	29	27	25	23	21	19	17	16	14	12
67	30	28	26	24	22	20	19	17	15	13
68	31	29	27	25	23	21	20	18	16	15
69	32	30	28	26	24	23	21	19	18	16
70	33	31	29	27	25	24	22	20	19	17
71	33	32	30	28	27	25	23	22	20	18
72	34	33	31	29	28	26	24	23	21	19
73	35	34	32	30	29	27	25	24	22	20
74	36	34	33	31	29	28	26	25	23	21
75	37	35	34	32	30	29	27	26	24	23
76	38	36	34	33	31	30	28	27	25	24
77	39	37	35	34	32	31	29	28	26	25
78	39	38	36	34	33	31	30	28	27	25
79	40	38	37	35	34	32	31	29	28	26
80	41	39	38	36	35	33	32	30	29	27

Table 13 (continued)

Relative Humidity, Per Cent.—Fahrenheit Temperatures. Pressure 30.0 Inches

Thermometer in Degrees

21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	26.0	26.5	27.0	27.5	28.0	28.5
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
3	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..
6	4	2	0	..	..	..	..	..	..	..	..	..	..	..	..
7	6	4	2	0	..	..	..	..	..	..	..	..	..	..	..
9	7	5	4	2	0	..	..	..	..	..	..	..	..	..	..
10	9	7	5	3	2	0	..	..	..	..	..	..	..	..	..
12	10	8	7	5	3	2	..	..	..	..	..	..	..	..	..
13	11	10	8	6	5	3	1	..	..	..	..	..	..	..	..
14	13	11	9	8	6	5	3	1	..	..	..	..	..	..	..
15	14	12	11	9	8	6	4	3	1	..	..	..	..	..	..
17	15	13	12	10	9	7	6	4	3	1	..	..	..	..	..
18	16	15	13	12	10	9	7	6	4	3	1	..	..	..	..
19	17	16	14	13	11	10	8	7	5	4	3	1	..	..	..
20	18	17	15	14	13	11	10	8	7	5	4	3	1	..	..
21	20	18	17	15	14	12	11	9	8	7	5	4	3	1	..
22	21	19	18	16	15	13	12	11	9	8	6	5	4	3	1
23	22	20	19	17	16	14	13	12	10	9	8	6	5	4	3
24	23	21	20	18	17	16	14	13	11	10	9	8	6	5	4
25	23	22	21	19	18	17	15	14	13	11	10	9	7	6	5
26	24	23	22	20	19	18	16	15	14	12	11	10	9	7	6

of water equal to about three hundred times the weight of the dry matter which they contain. The amount of water in the soil is also an important consideration. The more water a soil contains the less air it will have. The presence of too much water in the soil often brings about serious complications in the health of plants such as suffocation of the roots, weak growth and a loss in power of resistance.

The improper use of water may affect the physical structure of the soil and injure the plants. The careless dashing of water on the surface of hothouse benches will compact and puddle the soil, and tend to wash down the smaller grains to the bottom, changing thereby the capacity of that soil to retain air or heat, and thus indirectly affect the health of the plants.

Greenhouse plants depend on irrigation for their water entirely. Surface watering is still in use by the majority of hothouse men. But at best, this method often does no more than pack the soil instead of saturating it. Moreover, while safe enough for the experienced grower, it becomes extremely unsatisfactory when entrusted to careless or inexperienced labor.

Subirrigation

It has been hinted previously that subirrigation has not found general favor with greenhouse men. Yet this has proved both experimentally and in practice to be far superior to any other form of

greenhouse irrigation. In subirrigation water is applied through tiles underground.

Effect of Subirrigation on Vegetable Crops. Investigations by Rane* have clearly shown that parsley, tomatoes, long rooted radishes and spinach are greatly benefited by subirrigation. Lettuce, especially, seems to be most favorably influenced by this method of watering (fig. 12, a-c.). Little is known of the effect of subirrigation on flowering plants. Investigations along those lines are especially desirable.

From the health viewpoint, subirrigation should appeal to greenhouse men. Where lettuce drop is prevalent subirrigation seems to check it materially. The same is also true of damping off.

In the greenhouse, subirrigation may be adapted to any form of bed used, whether raised or solid. In either case the bed should be practically watertight. To prevent the rotting of wooden beds Taft † recommends coating the inside of the beds with a cement made of one part of water lime and three of sharp sand. This is made into a thick paste and spread over the surface about one-fourth of an inch thick. For a bed with tile or slate bottoms a similar covering will render them sufficiently tight. With wooden benches it is desirable that the supports be close enough to prevent sagging of the beds. In case of solid beds, a tight bottom about eight inches below the intended level of the bed is

*Rane, F. W., West Virginia Agr. Expt. Sta. Bul. 33: 255-270, 1893.

† Taft, L. R., Year Book, U. S. Dept. of Agr.: 233-246, 1895.

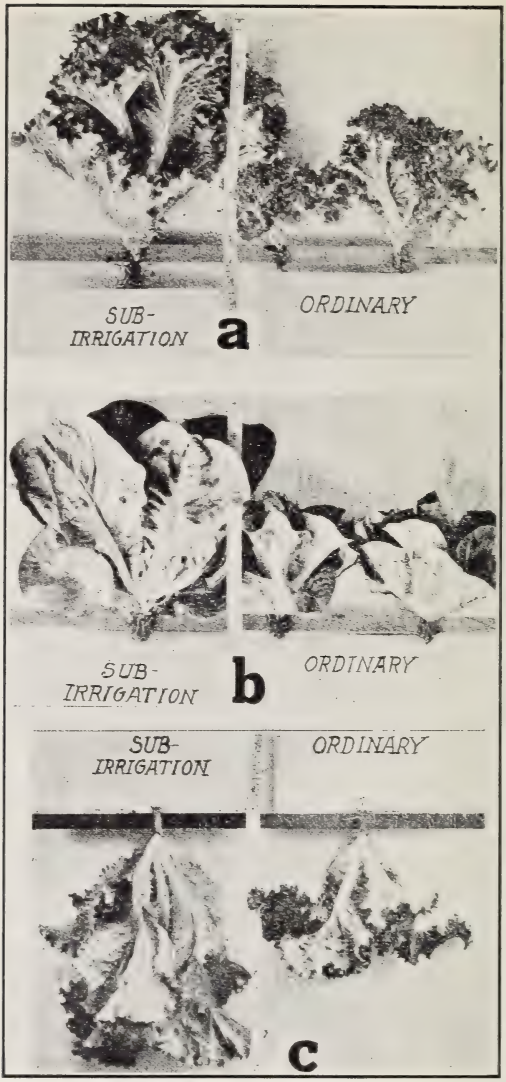

Fig. 12. Effect of Subirrigation on Lettuce.

a. Boston curled, *b*. Frankford head (*a-c* after Rane, F. W.).

necessary. If the subsoil is a stiff clay it may be desirable to spread an inch of gravel. After thoroughly ramming it is covered with a thin layer of the cement as described above.

Overhead Irrigation

This method is in greater use than any other practice of greenhouse watering. The advantages claimed for it are the cheapness of installation and the more uniform way in which the water is applied. By this method, too, the dry atmosphere of the house can be quickly changed. This is especially desirable during the hot summer days. The disadvantages of this system are the packing of the surface soil and the encouragement of disease through the excessive moisture applied to the plant.

Ventilation

Next to watering, ventilation is of utmost importance from the health viewpoint. Many of the plant diseases which are confined to the greenhouse are encouraged by improper ventilation. The lack of it is as harmful as an excess. The practical grower will give this careful thought and consideration. As a rule, plenty of ventilation should be given whenever weather conditions permit it, avoiding, however, draft and strong air currents.

CHAPTER 6

BREAKING THE REST PERIOD OF PLANTS

THE object of greenhouse culture is to grow certain crops or blooms at a time and season when these cannot be produced outdoors. All plants undergo a period of rest. Bulbs, for instance, enter their resting state when the leaves all die. No matter how cold, warm or wet, bulbs will not grow again before the fall. Howard* has found that it is very difficult to shorten this dormant period, at least during the earlier phases of the rest. He further found that of all treatments, drying, followed by injection with ether and Knop's solution (made up as follows: Calcium nitrate 1 gr., magnesium sulphate 25 gr., acid potassium phosphate 25 gr., and water 1 liter.), and combinations of these were most effective in shortening the rest period of bulbs. The injection may be accomplished by piercing the bulb with a hypodermic needle. Herbaceous perennials, too, like the bulbs, undergo a rest period. Frost, drying, and ether appear to be the most effective agents in breaking this rest period. To treat plants with ether, a galvanized iron chamber is preferred. The latter as used by Howard is shaped like a cylin-

* Howard, W. L., Missouri Agr. Expt. Sta., Research Bul. 15: 3-25, 1915.

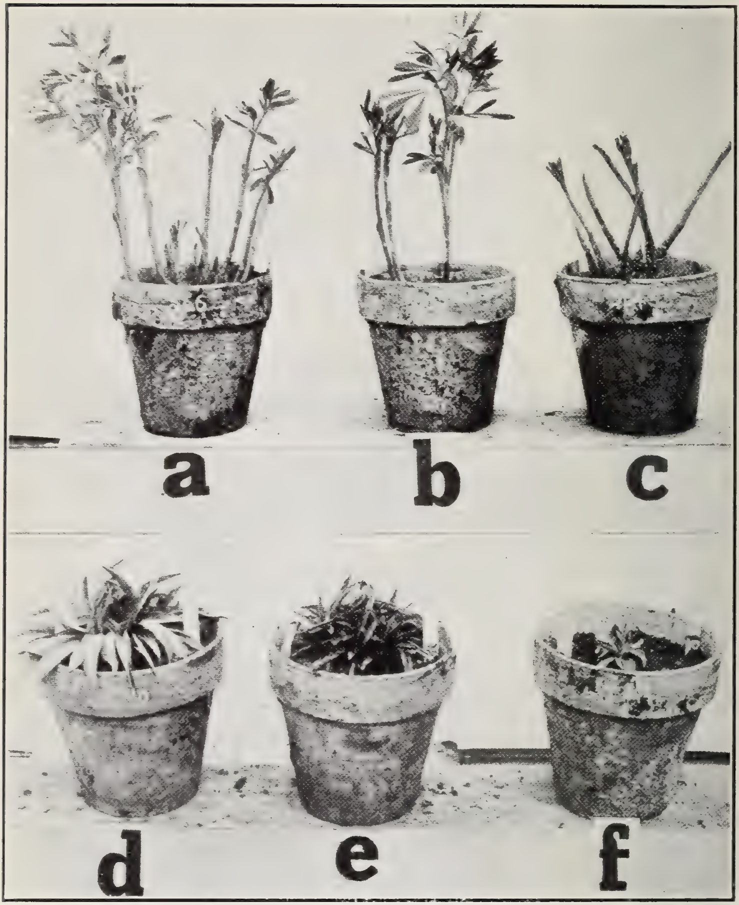

Fig. 13. Effect of Etherization on Plants.

b. Baptisa australis, 24 hours; *c.* check; *a.* 12 hours, *f.* Stokesia cyanea, check, *d.* etherized 24 hours; *e.* etherized 12 hours (*a-f* after Howard, W. L.).

der, with a diameter of about two feet and is made in two sections, each about three feet in length. The lower section is fitted with a bottom and at the top, around the rim, with a groove which is filled with fine sand. The rim of the upper section flares out so as to accommodate a lid. The latter fits in tightly by being forced down in the sand. The second section of the cylinder is like the first, except that it is bottomless. When treating a large number of plants at one time, the second section is placed upon the first, the lower end being forced into the sand. The ether is poured in through an opening in the lid, which may be tightly closed by means of a screw cap. The amount of ether used is at the rate of 40 grams to each 100 meters of space. The lid is weighted with bricks to prevent its being pushed off by the ether vapor. Treatments should preferably be given in the afternoon, or where there is no likelihood of changes of temperatures. The results of the treatment are summarized by Howard in Table 14 on following page.

From Table 14, it is seen that with certain plants etherization breaks the rest period and hastens growth (fig. 13, a-f.) while with others the treatment has the opposite effect. In his investigations Howard* further found that the rest period of a large number of woody plants may be largely overcome by ether treatment (fig. 14, a-b.). On the whole, how-

*Howard, W. L., Missouri Agr. Expt. Sta., Research Bul. 16: 3-27, 1915.

TABLE 14

Species of Plants	*Check*		*Frozen 24 Hours*		*Dried 8 Days*		*Etherized 5 Hours*		*Etherized 12 Hours*		*Etherized 24 Hours*		*Etherized 48 Hours*	
	Growth Began in Days	*Fully Open in Days*	*Growth Began in Days*	*Fully Open in Days*	*Growth Began in Days*	*Fully Open in Days*	*Growth Began in Days*	*Fully Open in Days*	*Growth Began in Days*	*Fully Open in Days*	*Growth Began in Days*	*Fully Open in Days*	*Growth Began in Days*	*Fully Open in Days*
Aquilegia sp.	†	†	‡8	‡15	†	†	*15	‡110	*120	†	*112	*126	†	†
Armeria maritima splendens, Boiss.	†	†	‡8	†	†	†	†	†	*79	*82	†	†	†	†
Asparagus officinalis, L.	‡27	‡61	‡10	†	‡28	†	—	—	—	—	‡56	†	‡9	†
Baptisia australis, R. Br.	‡3	‡54	—	—	‡79	*119	—	—	‡14	‡25	—	—	‡5	‡34
Cassia Marylandica, L.	‡36	‡54	‡46	‡74	‡32	†	—	—	—	—	—	—	‡46	†
Chrysanthemum sp. var. King Edward VIII	†	†	‡10	†	†	†	†	†	†	†	†	†	†	†
Clematis sp.	†	†	‡8	‡16	‡5	‡18	‡12	‡19	—	—	‡9	‡17	‡8	‡12
Convallaria majalis, L.	‡52	†	—	—	‡42	‡54	‡21	†	—	—	—	—	—	‡44
Dahlia sp.	‡15	‡40	†	†	‡22	‡25	—	—	—	—	—	—	‡17	‡20
Dianthus Chinensis, L.	*15	*27	‡10	†	*46	*54	*66	‡101	*70	*95	*45	†	*41	*51
Dirca palustris, L.	†	†	†	†	‡57	‡99	‡116	†	†	†	‡65	†	‡37	‡63
Eupatorium purpureum, L.	‡77	†	‡92	‡96	‡48	‡52	—	—	—	—	‡35	‡41	‡24	‡33
Gladiolus sp.	‡35	‡46	‡9	‡29	‡24	‡37	—	—	—	—	‡29	‡40	‡12	‡25
Helenium midiflorium, Nutt. var. Grandicephalum striatum	†	†	‡18	‡22	†	†	†	†	†	†	†	†	†	†
Heuchera sanguinea, Engler.	‡25	‡28	—	—	‡22	‡24	‡28	‡32	—	—	‡22	‡26	—	—
Kniphofia aloides, Moinch.	‡13	‡101	†	†	†	†	†	†	—	—	—	—	‡9	†
Liatris pycnostachya, Michx	‡24	‡34	—	—	—	—	‡13	‡20	—	—	—	—	—	—
Lilium tigrinum, Andr.	‡24	‡42	‡18	‡25	‡15	‡32	—	—	—	—	‡10	‡23	‡8	‡22
Myosotis sylvatica, Hoffm. var. alpertris	†	†	†	†	†	†	†	†	†	†	*58	*75	*61	*68
Peony sp.	‡34	†	‡5	‡35	‡26	‡52	‡18	‡41	‡14	‡39	‡9	‡34	‡5	‡20
Phlox sp.	†	†	‡9	‡20	‡21	‡31	‡25	‡31	‡11	‡13	‡19	‡24	‡2	‡7
Physostegia Virginiana, Benth. var. alba	†	†	‡7	‡44	†	†	†	†	—	—	—	—	—	—
Platycodon sp.	‡32	‡36	‡14	‡23	‡49	‡57	—	—	—	—	‡25	‡29	‡35	‡43
Polianthes tuberosa, L.	†	†	†	†	†	†	†	†	†	†	‡53	‡60	‡41	‡50
Rheum Rhaponticum, L.	‡20	‡29	‡18	‡27	‡20	‡30	—	—	—	—	—	—	‡4	‡13

* Flower bud. † No growth. ‡ Leaf bud. — Treatment not given.

Fig. 14. Effect of Etherization on Hybiscus Syriacus.

a. Etherized 48 hours, *b.* check (after Howard, W. L.).

ever, the use of anæsthetics is still in the experimental stage, although much that has been already discovered could be applied with great advantage commercially.

PART III

DISEASES OF GREENHOUSE VEGETABLES

CHAPTER 7

NATURE OF PLANT DISEASES

The successful greenhouse operator will realize the necessity of recognizing readily any plant disease. Very often this is overlooked and attention is attracted only when the trouble takes the form of an epidemic, and a large number of plants are thus carried off by it.

Plant diseases are usually of four kinds:

1. Those of a mechanical nature.
2. Those brought about by physiological disturbances or unfavorable environment.
3. Those brought about by parasitic flowering plants, fungi or bacteria.
4. Diseases the cause of which is unknown.

A familiarity with the symptoms of diseases will enable us to determine the contagious nature of the trouble and often the methods of control to pursue. The following outline* briefly summarizes the principal symptoms of disease in plants:

1. Discoloration or change of color.
   a. Pallor, yellowish or white instead of the normal green.

* Adapted with slight modifications from Heald, F. D., Texas University Bul. 135, Sc. ser. No. 14: 7-8, 1909.

b. Colored areas or spots.

White or gray, such as mildews, white rusts, etc.

Yellow, many leaf spots.

Red or orange, rusts, leaf spots.

Brown, many leaf spots.

Black, black rusts.

Variegated, leaf spots, mosaic

2. *Shot hole*, perforation of leaves.
3. *Wilting*, wilts, damping off.
4. *Necrosis*, death of parts such as leaves, twigs, stems, etc.
5. *Atrophy*, dwarfing or reduction in size.
6. Malformations or excrescences, galls, pustules, tumors, cankers, rosettes.
7. Exudation, slime or gum flow.
8. Rotting, dry or soft rots.

1. Diseases of a Mechanical Nature

Greenhouse plants, contrary to those grown outdoors, are open to but few injuries of a mechanical nature, for it is seldom, indeed, that indoor plants are injured by rain, hail, or frost.

Sunburn. While most greenhouse crops require a great deal of light, a few are injured by it. Some varieties of tomatoes, the Earliana especially, under the influence of strong sunlight are subject to sunscald. Sunburn may be overcome by shading the glass. Of the various shading materials, the cheapest and quickest to use is air-slaked lime. The

most expedient to use is air-slaked lime which has been slaked dry by sprinkling lightly with water. This is diluted in water and applied as a spray. If new lime is used it will be more difficult to wash off later. Moreover, it seems that air-slaked lime sticks a good while, but rubs off easily. It is far more desirable to use shading material that must be applied twice in the summer than something that will stick hard and remain during the fall and winter season.

Smoke injury. As a rule large greenhouse establishments are situated near large cities which are centers of industrial production and manufacture. Greenhouse plants are often injured from the effect of smoke or gases which escape from the furnaces into the air.

The sources of smoke may be classified into three divisions: (1) Smoke from large buildings or from manufacturing plants; (2) Smoke from locomotives; (3) Smoke from chimneys of dwelling houses. Smoke is generally produced because of improper furnace construction, such as improper draft, overloaded boiler, insufficient air space, insufficient air supply to boiler room, and also by carelessness of operation.

Smoke contains large quantities of carbon dioxide, steam and sulphur dioxide, besides its characteristic soot. The latter consists of carbon, tar, and mineral matter mixed with small quantities of sulphur, arsenic and nitrogen compounds which are of an acid nature. Soot adheres to plants, especially to

foliage, giving them a burned, contorted appearance. Another effect of soot and smoke is to close up the stomata or respiratory openings of the leaf, so that asphyxiation results. The effect of smoke on plants is a loss of leaflets in case of compound leaves, and an abnormal curling and distortion. Lesions and spots may be formed on the foliage as a result of the sulphur dioxide which is present in smoke. The spots are at first small, but soon enlarge and finally involve the whole leaf, which dries and becomes gray. Smoke injury, although of a mechanical nature, may also be considered from a physiological point of view. The after effect of smoke on plants resolves itself into a question of insufficient food supply and assimilation. This is indirectly brought about by diminished illumination, interference with the normal transpiration and the reduction of leaf surface.

Methods of Control. There is as yet no definite method of control known, consequently all that can be done is to avoid the smoke belts. The greatest injury usually occurs in locations to the leaward of smoky districts and when the soil is wet. As far as possible, therefore, postpone irrigation during the windy days.

2. Physiological Diseases

In this class are included disturbances which are due to unfavorable conditions of nutrition. There are numerous diseases of plants which are brought

about by lack of, or by an excess of, certain food elements in the soil. The effect is an interference with the proper life functions of plants.

Malnutrition

Symptoms. The symptoms of malnutrition are not always the same. They differ somewhat with the crop, the nature of the soil, and the fertilizer applied. In malnutrition the symptoms to be looked for are retarded growth, change of color in the foliage and root injury. Affected plants remain dwarfed at a time when maximum growth is expected. The color of the foliage turns a lighter green, especially in the spaces between the veins, which become yellowish green to brown. Roots of such plants are poorly developed, and secondary roots are often missing.

Causes of Malnutrition. The work of Stone*, and Harter † and others seems to have established the fact that malnutrition cannot be attributed to the work of parasitic organisms. Stone cites instances where constant watering with liquid fertilizers or manure would cause malnutrition in cucumber plants. The same is also induced when pig and cow manure are mixed, or when manure is worked into a soil already well fertilized otherwise. Harter records cases of malnutrition brought about by an

* Stone, G. E., Massachusetts Agr. Expt. Sta., Ann. Rept., 5-13: 1910.

† Harter, L. L., Virginia Truck Expt. Sta., Bul. 1: 4-16, 1909 (Norfolk, Va.).

excess of acidity in the soil. In soils where plants suffer from malnutrition, from 3,500 to 6,000 pounds of lime per acre area are often required to neutralize the excess of the soil acidity. This condition is apparently the result of intensive trucking and the heavy application of chemical fertilizers which leave the soil acid. Sulphate of ammonia, muriate and sulphate of potash and acid phosphate when used continuously will leave the soil in a very acid condition. On the other hand, nitrate of soda, carbonate of potash and Thomas phosphate tend to make the soil alkaline.

Another important cause of malnutrition is the exhaustion of humus. This is a natural result where commercial fertilizers are used instead of some form of organic manure.

Methods of Controlling Malnutrition. It is quite obvious from what has already been said, that the greenhouse grower is the loser if he uses his fertilizer injudiciously. Not only is malnutrition favored by such a course, but the yields, too, are considerably reduced. With acid soils, liming to neutralize the soil acidity will help control malnutrition.

Chlorosis

This disease may be attributed to several causes. Greenhouse plants that receive too much shade will become yellowish, then whitish, and in time may lose all their green color and finally die. Chlorosis is often brought about when plants grow in soils

that have become too alkaline. This is true for soils containing an excess of lime, wood ashes, or magnesia, and especially when nitrate of soda is used in excess.

Control. Chlorosis when brought about by the lack of available iron in the soil may be remedied by the application of small quantities of iron sulphate. If the disease is caused by the other factors previously mentioned, a cure may be effected by removing the cause.

Blossom Drop

This is another trouble which may be termed physiological and the cause of which cannot be attributed to the work of parasitic organisms. It is often noticed on tomatoes and various other plants. Various causes lead to it. Sudden drops of temperature at blossoming will induce many plants to shed their blossoms. Blossom drop may also be brought about when too much nitrogen is applied to the soil in the form of manure, especially hen manure. To overcome this, the fertilizer in the soil must be balanced by the addition of 600 pounds of acid phosphate and 150 pounds of muriate of potash per acre. Overacidity in the soil may also cause the shedding of blossoms. A sudden checking of the water supply, or overwatering may have the same effect. Finally, improper pollination is often one of the main causes for the blossom drop of greenhouse plants. In the field, pollination is favored by both

wind and insects. In the greenhouse, these two agencies are practically shut out. With forced cucumbers, the difficulty is often overcome by installing beehives in the house. Bees are very active under high temperature conditions, and perfect pollination is the result. The usual practice is to supply a beehive to every 200 feet of house. The hives should be placed on platforms several feet above the bed to protect the bees from becoming drenched during the watering or sprinkling of the beds. We should bear in mind that the hives must be taken out whenever the house is fumigated with potassium cyanide. Nicotine fumes do not seem to injure the bees, especially if the fumigation is carried on at night. Bees may be used to pollinate practically every crop grown in the forcing house. It seems, however, that bees refuse to work on tomatoes, perhaps because of a dislike for their nectar. In this case, then, it is necessary to pollinate by hand. The investigations of Fletcher and Gregg* and others have shown that the setting of a good crop of smooth heavy tomatoes depends largely on the proper distribution of pollen over the stigma. A lack of pollination will of course result in no crop. An uneven distribution of pollen will result in too large or irregular fruit. During the winter and on sunny days, it will pay to go over the plants and tap each blossom with the finger or with a stick on which is fastened a small glass rod or spoon. This

* Fletcher, S. W., and Gregg, O. T., Michigan Agr. Expt. Sta., Special Bul. 39: 2-10, 1907.

will shake out the pollen and enough of it will be liberated by this operation to insure complete fertilization. A high temperature will favor the maturing and the bursting of the pollen sacs even during cloudy weather. It is, therefore, advisable to run up the temperature of the house as high as is expedient on the days when the tapping of the blossoms is done. This should always be done during the day and never at night. The pollen sacks (anthers or male organs) do not burst freely until after the yellow petals have fully expanded and have begun to wither slightly. The pollen is discharged most freely in a hot dry atmosphere.

3. Diseases Brought About by Parasitic Flowering Plants or Micro-organisms

In this class of diseases may be mentioned those which are induced by parasitic flowering plants such as the dodder and the broom rape. These, however, as well as the diseases induced by bacteria and fungi, will be considered under their respective hosts.

Carriers of Diseases. In the greenhouse, disease producing organisms are often brought directly with infected soil or manure in the compost. *Fusarium lycopersici* Sacc., the cause of sleeping sickness of tomato, as well as large numbers of other parasites, are brought in that way.

Little as yet do we realize the importance of insects as carriers and disseminators of plant diseases, although we are becoming increasingly aware of

their rôle in human and animal pathology. Acting as carriers of spores of parasitic fungi, which may adhere to any part of their body, they are responsible for distributing plant diseases. Insects, too, by feeding on plants or in searching for the nectar of the blossoms, are likely to come in contact with diseased parts. Their bodies may become coated with spores of parasitic bacteria or fungi, which are thus carried from plant to plant and from field to field. The striped cucumber beetle is known to carry the virus of cucumber mosaic, and the germ of cucumber wilt (*Bacillus tracheiphillus* Ew. Sm.). It is therefore very essential that every effort should be made to keep insect pests out of the greenhouse.

4. Diseases of Unknown Origin

Mosaic

In this class will be included those diseases which spread by contact, but the exact cause of which is unknown. Special emphasis will be given to that important disease known as mosaic. This trouble attacks a variety of greenhouse plants. It is especially severe on the tomato, cucumber, and sweet pea.

Symptoms. Mosaic is readily distinguishable by a yellow dotting or mottling on the foliage, presenting in some instances a beautiful mosaic structure, whence its name. Affected leaves linger and often curl.

Cause of Mosaic. The cause of Mosaic is as yet a disputed question.* Allard claims that mosaic is caused by an ultra-microscopic pathogen, that is, a parasitic organism which cannot be detected by our present technic in microscopy. Mosaic may be transmitted from plant to plant. The easiest way to prove this is to rub with the fingers a diseased leaf and then immediately rub a healthy one. The disease will appear on the inoculated host in about ten days. In the greenhouse, the green aphid and the white fly act as carriers of mosaic.

Control. Methods of control in mosaic lie in the direction of prevention. Diseased plants should be destroyed by fire, and all indoor insect pests kept in check.

* See also Taubenhaus, J. J., Truck Crop Diseases, E. P. Dutton Co., 1918, New York, N. Y.

CHAPTER 8

GERMINATION TROUBLES

Diseased Seed. Numerous failures in germination may be directly attributed to diseased seed. These may carry infection internally in the form of mycelia in the invaded tissue. Seed may also carry infection material externally in the form of spores or sclerotia adhering to the seed coat.

Age of Seed. In determining the cause of poor germination, the age of the seed is to be considered, for after a certain age limit deterioration sets in. Each kind of seed has its own age limit, which is generally determined by the character of the seed itself, *i.e.*, whether oily or starchy, or lacking in both. Thus the vitality of the minute seed of tobacco is perhaps eight times as great as that of the large oily seed of the castor bean. With many species of seed there are apparently no external symptoms to indicate loss of vitality due to age.

Cultural Conditions. The viability of seed is also largely determined by the conditions undei which the previous crop grew. The more vigorous the mother plant the more vitality will there be imparted to its offspring. The vigor of the previous crop depends on favorable climatic conditions, care in

cultivation, and in fertilization. Old seed produced in a favorable season may be preferred to fresh seed of an inferior quality produced in a bad season.

Weight and Color of Seed. As a rule, light weight seed is inferior to heavy seed of the same variety. The weight of the seed is influenced by culture, and by imperfect fertilization which results in minute and weak embryos. The comparative weight of seed may be readily determined by the water method. Place the seed in a tumbler filled with water. After shaking and letting it stand for a few minutes, the heavier seed sink and the lighter float. Using this method, Stone * has shown that the heavier sinking seed give a higher percentage of germination than the lighter. (See Table 15.)

TABLE 15

Name of Seed	*No. of Seed Germinated*		*Per Cent. of Increase in Germination of Heavy Over Light Seed*
	Light	*Heavy*	
Lettuce	68	90	32
Onion	100	117	17
Onion	38	85	142
Lettuce	44	88	100
Onion	50	58	17
Average	60	87	61

The color of the seed does not seem to have any influence on the germination. Darker colored seed is usually preferred to the lighter of the same variety. Color, however, largely depends on the degree of ripeness.

*Stone, G. E., Massachusetts Agr. Expt. Sta., Bul. 121: 3-14, 1908.

Storage Conditions. The vitality of seed is greatly influenced by storage conditions. The longest lived seed may be ruined by improper storage. The ideal conditions of storage, however, are not always those which favor germination. Seed should be cured or dried before storing. The drier it is the less likely it is to spoil and the higher will be the temperature that it can stand. When large quantities of seed are to be handled by the trucker, it is advisable to build a seed house. The seeds are best kept in strong paper or cloth bags, placed in tin or galvanized iron cans.

Seed Testing. In buying seed we must never take it for granted that the germination will be perfect. To make sure, a sample of the seed should be tested for germination. The simplest method, perhaps, is to sow a definite number of seed in a shallow pan filled with moist sand, and kept covered in a warm, dark place. However, the fact that a seed sprouts does not always imply that it will develop into a normal plant. Hence, allowance should be made for this probability when making a test at home or in the seed laboratory.

Effect of Fertilizer on Seed. With the hope of hastening germination, greenhouse men often apply various fertilizers to the seed bed. This practice cannot be too strongly discouraged, especially when muriate of potash and nitrate of soda are used. These two fertilizers when used in strengths of one per cent. or more, inhibit the germination of the seed, whether applied directly or mixed with the

soil. Phosphoric acid or lime, when not used in excess, seems to have no injurious action on seed germination. However, on no account should commercial fertilizers be brought into direct contact with the seed. This is well brought out in Table 16 by Hicks.*

TABLE 16

Effect of Chemical Fertilizers on the Germination of Breakfast Radish Seed

Fertilizer Used	*How Applied*	*First Sprouts*	*Per Cent. of Germination*
Potash	In the rows	No sprouts	1.5
	Mixed with soil	No sprouts	1.5
Phosphoric Acid	In the rows	May 26	10.0
	Mixed with soil	May 24	95.0
Nitrogen	In the rows	May 25	2.0
	Mixed with soil	May 26	6.5
Lime	In the rows	May 24	37.5
	Mixed with soil	May 24	93.0
Mixed Fertilizer	In the rows	May 25	34.5
	Mixed with soil	May 24	92.0
Check, no fertilizer	....	May 24	96.5

Seed Treatment. Since seed is often a carrier of disease it is essential that it be treated before planting. Treating the seed for about ten minutes with sulphuric acid will hasten germination and destroy adhering spores of disease-producing organisms. However, more information is needed before this method can be universally adopted by the greenhouse grower. In practice, the safest method would be to soak all seed, before planting, in a solution

*Hicks, G. H., U. S. Dept. of Agr., Div. of Botany, Bul. 24: 5-15, 1900.

of one part of formaldehyde in 320 parts of water, *i.e.*, one pint of formaldehyde in 22 gallons of water. The soaking is carried on for 10 or 20 minutes, depending on the size of the seed and permeability of the seed coat.

CHAPTER 9

DISEASES OF GREENHOUSE CROPS

Asparagus (*Asparagus Officinalis*)

Cultural Considerations. Asparagus plants lend themselves admirably to forcing. It is now grown for commercial purposes on a fairly large scale indoors. Light is not essential for this crop. The beds may be in total darkness, although a diffused light is preferred. Any variety which produces large shoots is desirable for forcing. However, the variety Reading Giant has been developed for its resistance to rust, and therefore should be given preference. Forced asparagus may be grown in any soil, even sand or coal ashes, provided it contains plenty of organic matter. At the beginning of the forcing process, the temperature should not run higher than 45 to 50 degrees F. for at least one week. As soon as strong shoots are made, a temperature of 65 to 70 degrees is desired. In order to obtain high yields, profuse watering is necessary.

Diseases of Asparagus

Greenhouse asparagus seem to be subject to but few diseases.

Damping Off, see Rhizoctonia, p. 20.

Rust (*Puccinia aspargi* D.C.) seems to be of no importance as a disease of forced asparagus.

Bean (*Phaseolus Vulgaris*)

Cultural Considerations. Beans are not to be grown as a fall or winter crop. They are produced more easily and more profitably as a spring crop. In this case they follow well a winter crop of lettuce. The night temperature should not go below 60 degrees F. The best soil for bean culture is a rich light sandy loam. The soil should never be allowed to become damp and cold for any length of time. It must not be allowed to become packed and soggy through overwatering. As a safe guide to success, the crop should never receive a check in its growth in any period of its development. Of the varieties adapted to forcing may be mentioned, Black Valentine, Long Yellow Six Weeks, Kentucky Wonder.

Diseases of the Bean

Forced beans may be attacked by several important diseases.

Blight

Caused by *Pseudomonas phaseoli* Ew. Sm.

Symptoms. If the soil is too wet during planting time, the seed may rot in the ground and never germinate. At other times the roots of the young seed-

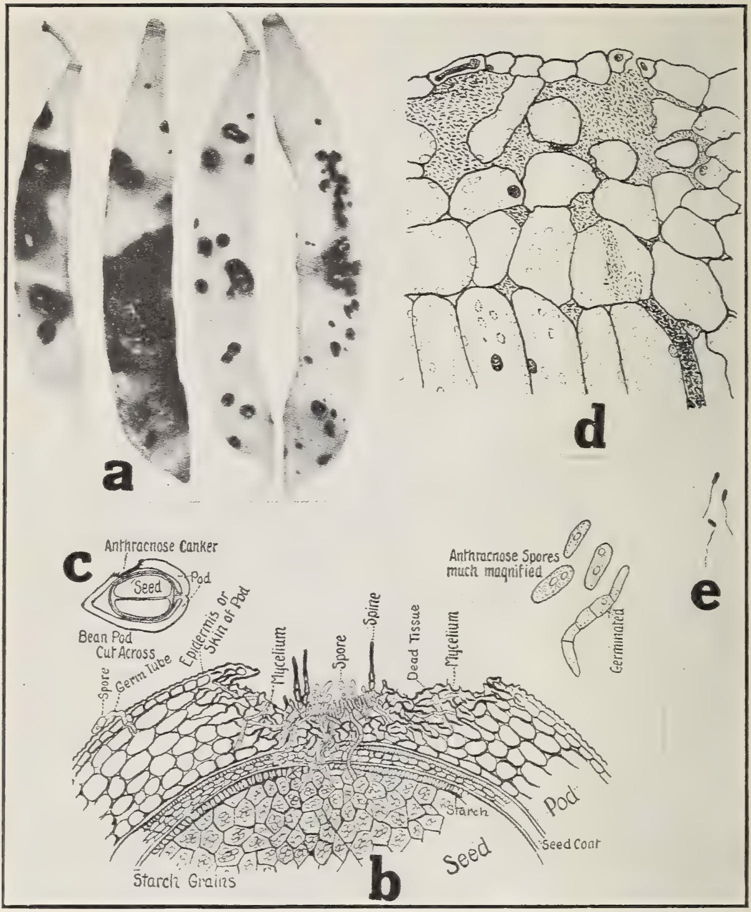

FIG. 15. BEAN DISEASES.

a. Anthracnose on pods (after Halsted), *b*. cross section of bean seed to show relationship of *Colletotrichum lindemuthianum* to its host, *c*. cross section of bean seed to show canker produced from anthracnose (*b-c* after Whetzel), *d*. cross section of bean tissue to show presence of the bean blight organism, *e*. *Pseudomonas phaseoli* (*d-e* after Smith, E. F.).

lings may decay and the result will be a very poor and uneven stand. Under drier conditions a better germination is obtained. The disease also works on the older plants, forming irregular spots. When their root system is attacked, affected plants become yellowed and wilted by daytime, but slowly revive at night. Should the air become muggy by overwatering and high temperatures, infected plants appear as though they have been drenched with hot grease, the leaves having a burned appearance. The injured plants then seem to make a desperate attempt to produce new foliage, which in turn becomes affected; the pods cease filling, and ripening is very uneven.

In carefully examining diseased seed, it is found to be yellowed and shriveled; or, in light cases of attack, covered with irregular yellow blotches. On the leaves, the trouble appears as watersoaked spots which later become amber colored. The cankers on the stems somewhat resemble the canker produced by *Colletotrichum lindemuthianum.*

The Organism. Pseudomonas phaseoli Ew. Sm. is a short rod, rounded at both ends, and motile by means of polar flagella (fig. 15, d and e.). It liquefies gelatin slowly, coagulates milk, and produces no gas. For methods of control, see Anthracnose, p. 112.

Sclerotinia Rot

Caused by *Sclerotinia libertiana* Fckl.

Sclerotinia rot is a disease which attacks snap

beans. During a period of several hot humid days the disease may suddenly break out in great severity. Usually withering and decaying of stems and pods where the plants are thickest is the first symptom that attracts attention. On closely examining infected stems and pods, we find that they are watersoaked, and overrun by a white mycelial growth on which appear numerous hard, black sclerotia. In the field, the Black Valentine snap bean seems to be more resistant to rot. For a description of the causal fungus and methods of control, see lettuce drop, p. 150.

Powdery Mildew

Caused by *Erysiphe polygoni* D. C.

Symptoms. Powdery mildew is a serious bean disease. It is characterized by white, mealy patches on the surface of the leaves and stems. The foliage soon turns yellow and dry. Powdery mildew may be controlled by dusting the plants with flowers of sulphur. Care in the proper amount of watering and ventilation will also help to keep it in check.

Anthracnose

Caused by *Colletotrichum lindemuthianum* (Sacc. & Magn.) B. and C.

Symptoms. Anthracnose is so characteristic that it cannot be mistaken for any other disease, except perhaps the blight. In light attacks, the seeds are

covered with sunken brown to black specks. These are especially evident on the white seeded varieties. In severe attacks, the seeds are covered with deep sunken black spots (fig. 15, c.) which are rifted in the center. On the leaves the disease attacks the veins, which become blackened and somewhat shrunken. Frequently it attacks the petioles, especially at the point of leaf attachment. In this case, the foliage drops off, leaving the bare petioles or stems. Anthracnose on the pods begins as small, circular, pin-point, dark red spots which enlarge, and later elongate into maroon colored pits, cracks, or cankers (fig. 15, a.). On young seedlings the stem rots off a short distance above ground.

The Organism. Spores are formed on the spots or cankers of all parts affected (fig. 15, b.). These are imbedded in a gelatinous substance and may become loosened only by water splashing upon it. It is at this stage that the disease becomes serious, for it is then spread from plant to plant. When the spores are lodged on a new bean plant or on a new part of the same plant, infection takes place through the penetration of the tube of the germinated spores.

Control. Spraying has not given satisfactory results. The best control is to plant clean seed selected from clean pods. The latter, before shelling, may be dipped for ten minutes in a solution of one part of corrosive sublimate to a thousand of water. The treated pods are then dried in the sun, shelled, and the seed put away in dry Mason jars until planting time. Should weevils threaten these seeds, they

may be fumigated with carbon bisulphide. Under no circumstances should infected plants be syringed. When this is done the spores of the fungus are scattered broadcast. Recently Burkholder * has succeeded in developing a resistant bean by crossing the Well's Kindney Bean with the White Marrow variety.

Root Rot, see Rhizoctonia, p. 20.

Root Knot, see Nematode, p. 28.

Beet (*Beta vulgaris*)

Cultural Considerations. Beets are not grown very extensively in the greenhouse. They are, however, raised on a small scale for greens or for the roots. It is often used as a companion crop with tomatoes. The Egyptian or any other early variety is preferable. The cultural requirements of the beet are the same as those of the lettuce, see p. 145. However, beets will grow more rapidly under higher temperatures than lettuce.

Diseases of the Beet

Indoor beets are subject to less diseases than those grown out of doors. The following are the more important ones:

Crown Gall

Caused by *Pseudomonas tumefaciens* Sm. and Town.

* Burkholder, W. H., Phytopath. 8: 353-359, 1918.

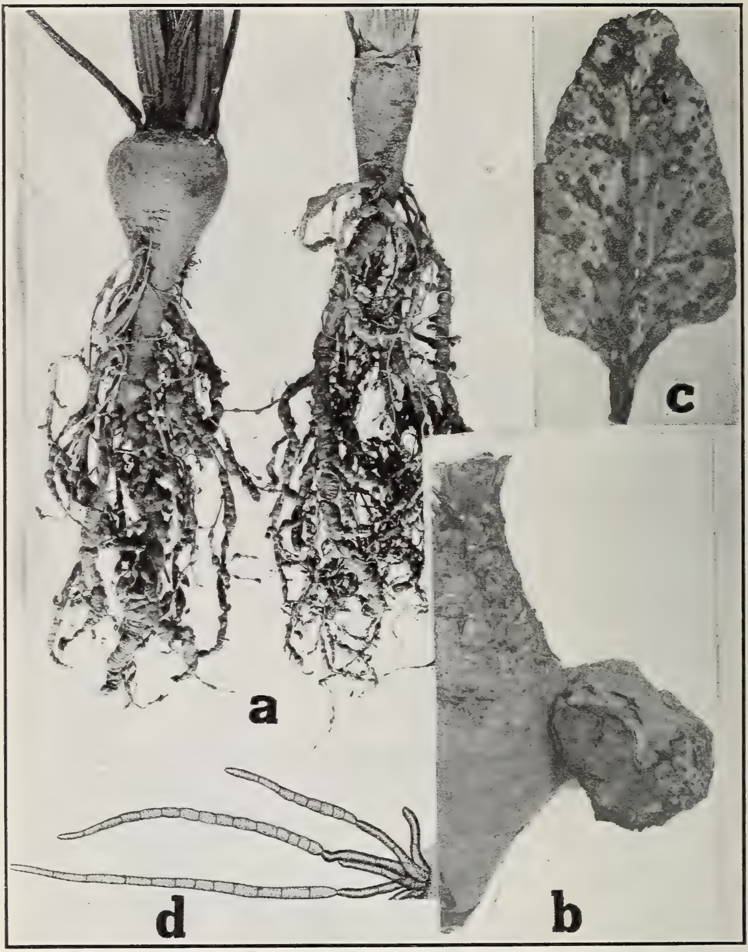

FIG. 16. BEET DISEASES.

a. Nematode or root knot, *b.* Crown gall, *c.* Cercospora leaf spot (after Halsted), *d.* spores of *Cercospora beticola* (after Schwarze).

Crown gall is a very important disease because of its cosmopolitan nature, for it is widely prevalent and attacks a large number of hosts.

Symptoms. The disease does not usually manifest itself until the roots are nearly half grown. Abnormal outgrowths or galls (fig. 16, b.) appear which vary in size from that of a garden pea to nearly two inches in diameter, according to the severity of the attack. The galls are usually attached to the beet by a narrow string. In light cases of infection there may be but one gall on the root; in severe cases, however, the roots may be covered with numerous galls.

The Organism. The cause of crown gall is a bacterial organism, *Pseudomonas tumefaciens* Sm. and Town. It is a short rod, multiplying by fission, and moves about by means of polar flagella. On agar or gelatin it forms small round white colonies. Under unfavorable conditions it readily develops involution forms; the organism is short lived in pure culture. *P. tumefaciens* lives over in the soil from year to year.

Control. The disease may be introduced with infected soil. Sterilizing the soil with steam or formaldehyde (see pp. 32-43) is recommended.

Scab

Caused by *Actinomyces chromogenus* Gasp.

Scab on beets is the same as the scab of the Irish potato, the radish, and the carrot.

Symptoms. The symptoms of the disease on beets do not differ from those of the Irish potato. Occasionally, the scabs which arise before the beet is full grown disappear entirely, leaving merely a small scar. This is somewhat sunken and has a definite outline. In normal cases of infection, the scabby areas on the beet are rough; while the corky layer of the spots decidedly bulge out. Immediately below them, the tissue is a discolored reddish brown.

The Organism. The cause of beet scab is the same as that of the scab of the white potato. The parasite is a soil organism, and thrives best under alkaline conditions.

Control. The disease is introduced with infected soil, or with the compost. Care should be taken that no infected potato peelings find their way to the manure pile. Soil sterilization with steam, or formaldehyde (see pp. 32-43) is recommended.

Damping Off and Root Rot

Caused by *Pythium de Baryanum* Hess.

Symptoms. Damping off very commonly occurs just as the seedlings emerge from the ground. These topple over and die in the characteristic way so familiar to truckers. The greatest damage follows from overwaterings, when a hard crust is formed on the surface, a condition which prevents the seedlings from emerging normally. On old and mature roots, *Pythium de Baryanum* may cause a rot. A pecu-

liarity of this disease is that it seldom starts at the top of the crown. The latter appears to be perfectly healthy, although the leaves turn yellow, indicating a diseased condition further down. Rotted roots are found to be overrun by a varied flora, although Pythium is the original cause of the trouble. For a further description of the organism see p. 17.

Control. The methods of controlling this disease are the same as those for lettuce drop, see p. 151.

Downy Mildew

Caused by *Peronospora schachtii* Fckl.

This disease is of little economic importance in the United States. The trouble, however, is prevalent in Europe. The mildew attacks the young seedlings in grayish patches on the under side of the foliage. On older plants, the mycelium of the causative fungus works downwards into the root, causing it to rot.

Drop

Caused by *Sclerotinia libertiana* Fckl.

Drop, which attacks young seedlings of the beet, but not the older plants, is not very different from a similar trouble on lettuce. The high temperature of the soil soon after making the hot bed, is important in favoring the disease. Sterilizing the soil with formaldehyde, careful regulation of temperature, and watering are methods to be observed in the control of the trouble.

Leaf Spot

Caused by *Cercospora beticola* Sacc.

There is perhaps no beet disease that is of greater economic importance than leaf spot. The trouble is well known to truckers and it seems to be found wherever beets thrive.

Symptoms. The disease first makes its appearance on the leaves as tiny circular whitish spots. These gradually increase in size and assume a brownish color. The spots soon multiply and involve the entire leaf area (fig. 16, c), which becomes dry and brittle. Leaf spot attacks the outer and older leaves first. As the inner foliage advances in age, they too become infected in turn. Serious though the disease may appear, it never kills the plant. The result, however, is noticeable on the roots, which are undersized and elongated instead of round. Leaf spot generally appears in overwatered and poorly ventilated houses. The disease increases in severity as the plants are weakened by heat.

The Organism. The fungus, *Cercospora beticola*, Sacc., like most fungi, is composed of a vegetative part of mycelium and of spores. The latter are microscopic in size, somewhat needle-shaped, and divided by means of a cross wall into cells numbering from two to seven (fig. 16, d.). Each of these cells may germinate by sending out a thread-like tube, which penetrates the leaves through the stomata. The spores are borne on a cluster of stalks or conidiophores, at the base of which is formed a small

stroma. The temperature and relative humidity of the air influence the production and infection of conidia. Conidia are generally formed on the lower surface of the leaves, no doubt because these are subject to a higher humidity.

Control. Infected material should be destroyed by fire. Spraying with Bordeaux mixture 4-4-50 is also recommended.

Root Rot

Caused by *Rhizoctonia solani* Kuhn.

Symptoms. This disease produces a damping off of the young seedlings, and on older plants a rotting of the crown. Upon pulling out an infected plant, we find that the outer leaves are dead and dry, while the inner ones are somewhat curled. The roots of such plants invariably are rotted at the crown, the rot generally working inwards to a considerable extent. The peculiarity of this disease is that the lower half of the root is generally sound. Frequently, the rotted crowns are also found to be cracked at various places. Beets thus affected are worthless for the market. For a description of the fungus see p. 20.

Control. There are no methods of control known. The factors which favor the trouble are poor drainage, an excess of soil moisture, and lack of sufficient ventilation. Every step taken to overcome these will in a degree help to control the rot. Soil sterilization is also recommended.

Root Knot, see Nematode, p. 28 (fig. 16, a.).

The organisms *Pseudomonas teutlium* Met., *Ps. beticola* Ew. Sm., *Urophlyctis leproides* (P. Mag.) Trab., *Cystopus bliti* (Biv.) Lev., *Uromyces betæ.* Kuhn, and *Phoma betæ* Fr. seem to attack beets out of doors only.

Carrot (*Daucus carota*)

Cultural Considerations. Carrots are forced in about the same way as the radish. The soil, however, should be more sandy. The variety best adapted for forcing is the early small topped Short Horn type.

Diseases of Carrots

Carrots are very hardy and subject to but few diseases of consequence.

Soft Rot, see Cauliflower, p. 126.

Root Rot, see Rhizoctonia, p. 20.

Cauliflower (*Brassica oleracea var. botrytis*)

Cultural Considerations. Cauliflower is not so extensively forced because large amounts of it are shipped from California during the forcing season. Nevertheless, indoor cauliflower is far superior in quality, and with the proper advertisement the forced product should gain greater recognition from the consumer. There are few varieties which lend themselves well to forcing. The Snowball and the Erfurt are preferred by most growers. The soil

should not be too heavy, although the plants are heavy feeders. The compost should contain a fair amount of well rotted manure. In addition, a well balanced fertilizer may be added at the rate of 1,000 pounds per acre. Lime should also be added to the beds at least once every two years. This will sweeten the soil in case it has a tendency to sour. Cauliflower requires an abundance of water. Lack of sufficient water may check the growth, an effect that will result in small or no heads. On the other hand, overwatering may produce an excess of foliage at the expense of head development. In warm weather, the plants and the walks should be syringed in order to keep the atmosphere moist. The best night temperature is about 50 to 55 degrees F. and the day temperature from 65 to 70 degrees. Plenty of ventilation should be provided; but drafts should be avoided.

CHAPTER 10

DISEASES OF CAULIFLOWER

INDOOR cauliflower seems to be subject to less diseases than that grown out of doors. The troubles which attack this plant are practically the same as those which are found on the cabbage.

CLUB ROOT

Caused by *Plasmodiophora brassicæ* Wor.

Symptoms. Affected plants show a wilting of the foliage in the day, although recovering in the evening or during cloudy weather. Diseased plants are dwarfed, pale, and sickly looking. The seat of the trouble is at the roots. The latter swell considerably in size, often taking on the form of a hernia (fig. 17, a-c.). The disease is more severe on seedlings in the seed bed, from whence it is carried to the field or to the greenhouse.

The Organism. Club root is caused by a slime mold. The spores of the parasite (fig. 17, d.) are nearly round and possess a transparent and refractive cell wall. The first signs of germination are a swelling of the spores, followed later by a bulging at one side. The inner pressure exerted splits the spore wall, thus permitting the protoplasm (swarm

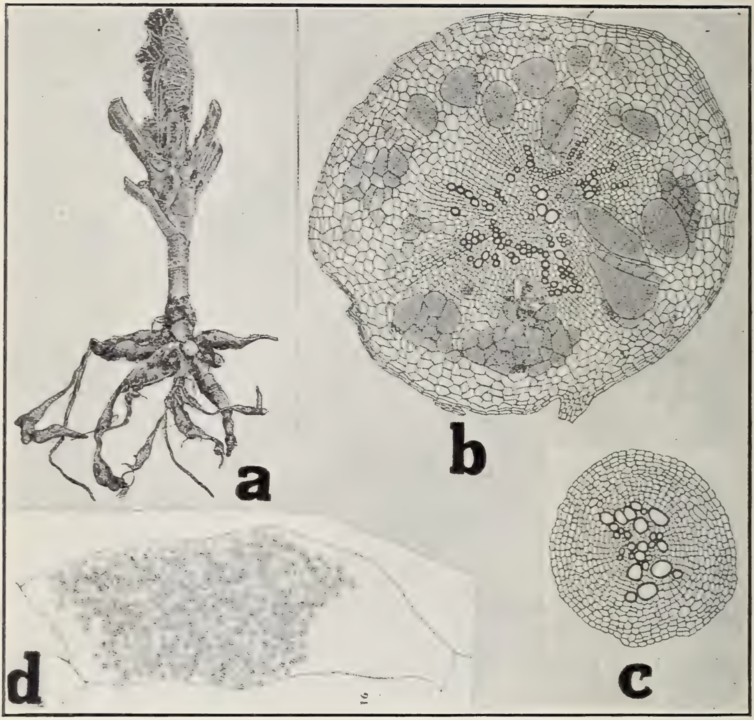

Fig. 17. Cauliflower Diseases.

a. Young cauliflower plant with club root (after Jones, L. R.), *b.* cross section of an infected root, *c.* cross section of a young healthy root (*b-c* after Woronin), *d.* host cell containing Myxomycete spores (after Lutman, B. F.).

spores) to ooze out. The latter is without a cell wall, and moves by means of a thick flagellum at the small end. The germination of the spores is improved by exposing them for a short time to cold and drying. The best medium is water which has been filtered through muck soil.

Infection of the hosts takes place through the wall of the root hair while the organism is in a uninucleate stage. Entrance of the parasite is evidenced by the browning and shriveling of the root hair.

Control. If this disease becomes introduced into the greenhouse, the safest course would be to sterilize the soil in the benches and in the seed bed. Sterilization with steam or formaldehyde is recommended (see pp. 32-43).

Bacterial Leaf Spot

Caused by *Pseudomonas maculicolum* McC.

Symptoms. The disease is characterized by numerous small brownish to purple-gray spots. When the small spots coalesce, the entire leaf surface may be involved. Practically all parts of the leaves are affected. When the midribs and veins are attacked, the tissue becomes shrunken, and the leaves have a puckered appearance. In the early stages of infection, the spots on the leaves are watersoaked, later they become dry and turn dark merging into purplish gray. In transmitted light, the centers of the spots are thin, almost colorless, and are surrounded

by a dark border. The diseased leaves become yellow and drop off prematurely. The trouble apparently does not attack the cauliflower head. The same disease may also attack the radish.

The Organism. The disease is produced by *Pseudomonas maculicolum*, a rod-shaped organism, with rounded ends, usually forming long chains in certain media, but producing no spores. The organism is actively motile by means of polar flagella. Involution forms are produced in alkaline beef bouillon; and pseudo-zooglœæ occur in acid beef bouillon. No gas is produced and the organism is aërobic. It is killed by drying and exposure to light.

Control. Badly diseased plants should be pulled up and destroyed. Spraying with 4-4-50 Bordeaux is recommended. In spraying cauliflower with copper compounds, and especially if the latter are in a concentration somewhat stronger than the plant can stand, numerous warts will appear on the leaves in about three days after spraying. These warts should not be mistaken for a disease induced by a parasitic organism. The wart formation is apparently due to a stimulation from the salts absorbed by the host cells.

Black Rot

Caused by *Pseudomonas campestris* (Pammel) Ew. Sm.

The disease is known both as stem rot and black rot. The latter perhaps is the more common name.

Symptoms. Black rot has distinct symptoms

which cannot easily be confused with other diseases. On the leaves, the symptoms are manifested as a burning appearance on the edges and a yellowing of all the affected parts except the veins, which remain blackened. From the margin of the leaves, the disease works downwards to the stalk. From there it travels up again to the stems and leaves. The parasite works in the fibrovascular bundles of the leaves and main stalk, causing a premature defoliation. Occasionally, the disease enters one side of the stalk, the latter becoming dwarfed and the cauliflower head grows one-sided. In severe cases of attack, there is a total lack of head formation. Upon splitting open a stump of an affected plant, one finds a black ring which corresponds to the places of the fibrovascular bundles invaded by the organism. Infection takes place through small openings naturally found on the leaves and known as water pores which are scattered over the teeth of the leaves. Infection by means of insect bites is also a very common occurrence. Outbreaks of black rot may undoubtedly be traced back to the use of infected manure. Black rot also attacks greenhouse radish.

The Organism. Pseudomonas campestris is a rod-shaped organism, slightly longer than it is broad. When young it is actively motile by means of long polar flagella. It is found single or in pairs and produces no spores. It liquefies gelatine completely in about fifteen days. On agar plates the colonies are round, yellow in color, and the margin entire.

On potatoes a liberal growth is produced with no odor and no browning of substance.

Control. Before planting, cauliflower seed should be disinfected for fifteen minutes in a solution of ¼ pint of pure (40%) formaldehyde diluted in seven gallons of water. In making the seed bed, manure known to be free from cabbage refuse should be used. All insect pests should be kept in check by spraying with arsenate of lead. The disease cannot be controlled by merely cutting off diseased foliage. If anything, this operation aggravates the trouble. Diseased plants should be pulled out and destroyed.

Soft Rot

Caused by *Bacillus caratovorus* Jones.

Soft rot, although a field trouble, causes considerable damage to greenhouse cauliflower.

Symptoms. The disease is characterized by a soft, mushy to slimy decay of the entire plant. The disease works very rapidly under favorable conditions of moisture and temperature. The causal organism can gain entrance only through a wound or bruise.

The Organism. Soft Rot is caused by a bacillus that is rod-shaped, of varying length, and usually formed in chains. It moves about by peritrichous flagella. It completely liquefies gelatine in about six days. Gas is produced with a majority of strains.

Control. Diseased plants should be destroyed by fire. To check further spread, water should be withheld and plenty of ventilation allowed. During

watering unnecessary splashing of soil particles on the plants should be avoided.

Damping Off

Caused by *Olpidium brassicæ* (Worr.) Dang.

The symptoms of damping off for cauliflower are similar to those produced by *Pythium de Baryanum*, p. 17. The sporangia of the parasite may be found singly or in groups in each infected host cell. The zoospores are globose, uniciliate. The resting spores are globose, wrinkled, and star-like in appearance.

The disease is found mostly in seed beds, where it does considerable damage. For methods of control, see pp. 32-34.

Downy Mildew

Caused by *Peronospora parasitica* (Pers.) De By.

Symptoms. Downy mildew, while a common field disease, causes considerable damage to young seedlings in the seed beds. It is characterized by whitish downy patches on the underside of the leaf. Seen from above, the affected areas are angular, pale yellow, and somewhat shrunken. The spots seem to be limited by the veins of the leaves. The disease is common in damp houses. Besides the cauliflower, the radish, and numerous other cruciferous hosts are known to be susceptible to downy mildew.

The Organism. The sporophores of the fungus are stout and numerously branched, each of these repeatedly forked. The tips of the smaller branches

are slender and curved. The conidia are broadly elliptical, and the resting spores are globose and smooth, becoming wrinkled with age.

Control. In the seed bed, spraying with 4-4-50 Bordeaux will control the disease. The first application should be given as soon as the disease makes its appearance. Later the application will be governed by disease conditions. Care should also be taken to avoid sowing the seeds too thickly. Overwatering, poor ventilation, and high temperature favor the disease.

Drop

Caused by *Sclerotinia libertiana* Fckl.

Drop is a disease fairly common on cauliflower. The trouble may be recognized by a drooping and wilting of the leaves. The bases of the affected foliage are covered with a white weft of mycelial growth, later by sclerotia. For a more extended discussion of the disease, see lettuce drop, p. 150.

Ring Spot

Caused by *Mycosphærella brassicæcola* (Duby) Lind.

Symptoms. On the leaves, the disease appears as numerous small spots and the affected foliage turns yellow. Most of the spots are formed on the laminæ, but others are also formed on the large midribs. The spots are definite in outline, round

and visible on both surfaces of the leaf. The color is light brown to gray, with dry centers surrounded by olive green or blue green borders which shade off into the natural color of the leaf. The outer edge of the spot is covered with the fruit of the fungus. Spraying with 4-4-50 Bordeaux is recommended.

Black Mold

Caused by *Alternaria brassicæ* (Berk.) Sacc.

Affected leaves are covered with spots which are nearly black on the under side of the leaf. The spots are composed of a series of rings, the smaller ones enclosed within the larger. There is no distinct border separating the diseased portions from the healthy; the spots gradually shade off into the healthy tissue. Little is known of the causative fungus or of the control of this disease. It is probable that spraying with 4-4-50 Bordeaux will be of value.

Root Knot

Caused by *Heterodera radicicola* (Greef) Mull.

Root knot is characterized by small swellings on the lateral feeding roots. For a description of the parasite and methods of control, see p. 28.

Celery (*Apium graveolens*)

Cultural Considerations. Celery has not yet taken its place among the standard forced vegetables. It

is possible, however, to produce celery in the greenhouse which is of a quality far superior to that grown out of doors. The self-bleaching varieties such as the Kalamazoo seem to be well adapted for forcing. The White Plume seems to have a tendency to go to seed, and the Golden Self-blanching is subject to heart rot. Celery requires an abundance of moisture. A lack of it will cause such a setback to the plants that they may never recover. Too high or too low a temperature has the same detrimental effect.

Diseases of the Celery

Celery is subject to numerous diseases. Success with the crop demands great care in the production of healthy plants.

Soft Rot, see Cauliflower, p. 126.

Late Blight

Caused by *Septoria petroselini* Desm. *var. apii* Br. and Cav.

Symptoms. The disease first attacks the lower leaves of the stalk, producing irregular spots without a definite boundary line. When the spots become numerous the foliage withers and dries up (fig. 18, a.). The disease attacks the leaves as well as the stalks, rendering the affected plants useless for the market. In storage, plants affected with late blight will keep very poorly or rot altogether.

The Organism. The fungus mycelium is hyaline,

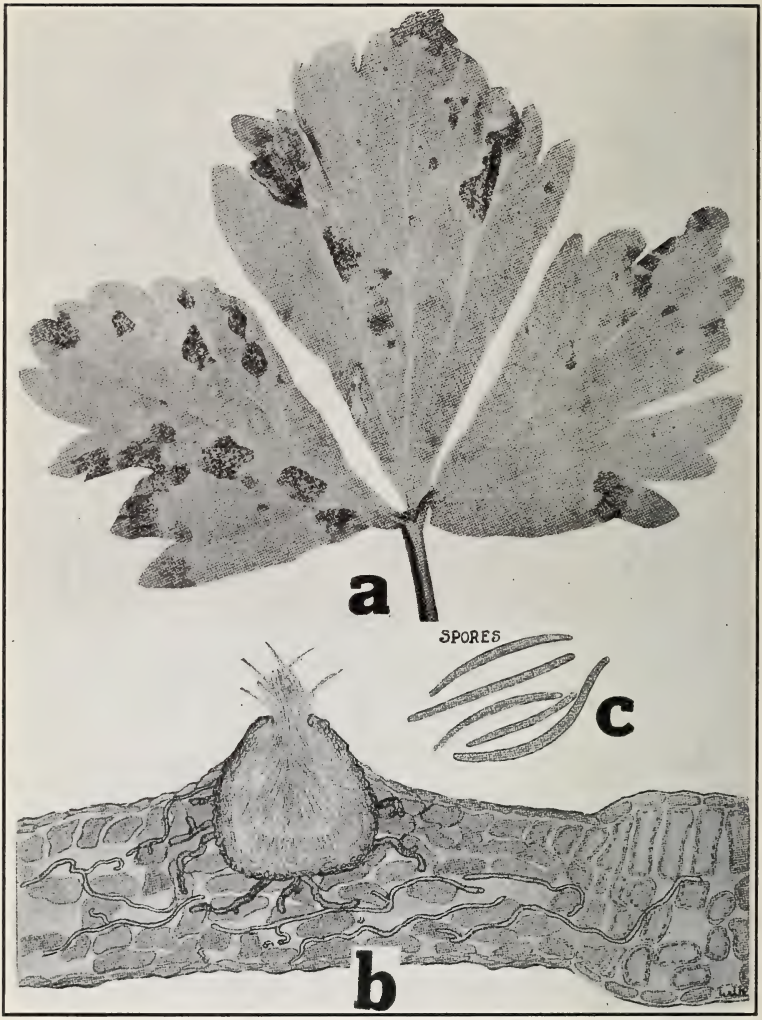

FIG. 18. CELERY DISEASE.

a. Septoria leaf spot, *b.* cross section through leaf to show relationship of fungus to its host, *c.* spores of *Septoria petroselini* (*a-c* after Coons).

septate. The pycnidia (fig. 18, b.) are olivaceous, prominent, and abundant in the spots. The pycniospores are filiform, straight or curved, hyaline and many are septate (fig. 18, c.).

Control. According to Rogers,* late blight may be controlled by spraying with 5-6-50 Bordeaux.

The first two applications should be given to the seedlings in the seed bed. In the house the first spraying should be administered about six weeks after transplanting. Besides spraying, shading also seems to keep the disease in check. In spraying celery, great care should be exercised to apply a fine mist. Where this is overlooked, large drops of the Bordeaux mixture may be deposited on the leaves and stalks, which upon drying may deposit copper salt in sufficient quantity to injure the consumer. Sprayed celery should be carefully washed and dried before shipping.

Early Blight

Caused by *Cercospora apii* Fr.

Symptoms. The trouble first appears on the outer leaves as pale blotches visible on both sides of the affected parts. The spots are irregular, angular in outline, limited apparently by the leaf veins, with slightly raised borders (fig. 19, a.). The spots later turn brown to ashy white.

The Organism. The conidiophores are usually

*Rogers, S. S., California Agr. Expt. Sta. Bul. 208: 83-115, 1911.

borne on the under side of the leaf, light brown, and in clusters. The conidia are hyaline, 3 to 10 septate, cylindric (fig. 19, b.).

Control. Early blight as well as late blight may be controlled by spraying with Bordeaux mixture. The Boston Market and Golden Heart varieties should be avoided because of their susceptibility to the disease. The White Plume seems to be resistant.

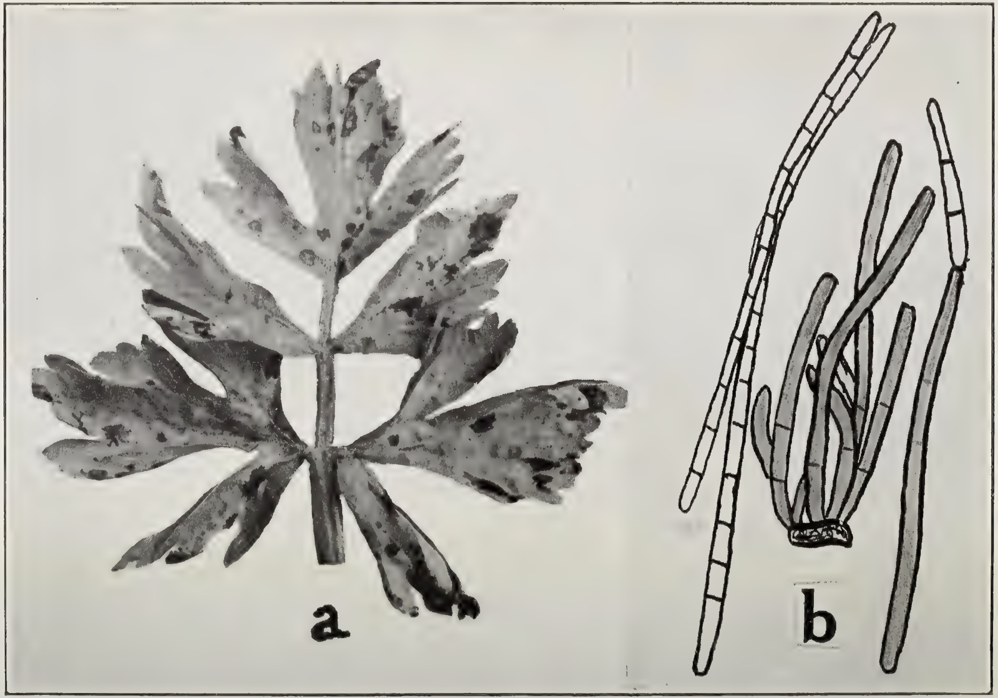

Fig. 19. Celery Disease.

a. Early blight on leaf, *b.* conidiophores and conidia of *Cercospora appii.*

CHAPTER 11

CUCUMBER (*Cucumis sativus*)

Cultural Considerations. Cucumbers are extensively forced for the winter or early spring markets. (fig. 20.) The houses generally used are either two-thirds or even-span and are provided with ground beds instead of benches.

Unlike lettuce, cucumbers are not so sensitive to variations in soil texture. A great variety of soils may be used if, however, they are well provided with organic matter. Cucumbers require a night temperature of about 65 degrees F. and about 85 degrees during bright weather. In cloudy weather, however, the day temperature should be about 10 to 15 degrees lower, otherwise the plants will become weak, spindly and susceptible to disease. Extreme care is required in watering the plants. Overwatering during cool, wet weather will greatly injure them by encouraging numerous diseases.

Of the varieties which lend themselves to forcing are the Telegraph (English), and all strains of Dark Spine and White Spine among the American varieties.

Diseases of the Cucumber

Cucumbers under glass are subject to a large number of diseases.

Leaf Curl

Cause, physiological.

Symptoms. The trouble is often manifested as a wilting of the edges of the leaves which curl into a spherical form. The wilted area soon dies, thus preventing any further development of the affected leaf. As the inner part of the leaf continues to grow and as it is restricted by its outer dead area, it assumes a convex form and a contorted margin, so that it curls up and assumes the shape of a ball. In advanced cases the stems, too, curl. The disease was studied by Stone * who believes that the cause of the trouble is overmanuring. Abnormal modifications in the light, soil texture, and moisture conditions may frequently induce the same trouble. To prevent this disease the use of excessive manures should be avoided. As far as possible, conditions which favor weak soft growth should be eliminated.

Malnutrition of Cucumbers

Cause, physiological.

Malnutrition generally results from an overfertilization of the soil. This trouble has been carefully studied by Haskins † who found it very prevalent on indoor cucumbers.

* Stone, G. E., Mass. (Hatch) Agr. Expt. Sta., Bul. 87: 3-43, 1903.

† Haskins, H. D., Mass. Agr. Expt. Sta. Twenty-fifth Ann. Rept.: 71-76, 1913.

FIG. 20. YOUNG HEALTHY GREENHOUSE CUCUMBER PLANTS.

Symptoms. At first, the plants have a vigorous appearance, but soon turn yellow and fail to form fruit. The leaves of affected plants become spotted, resembling somewhat mosaic.

Cucumbers are often grown in the same beds for a number of years. Each year as new manure and fertilizers are added, the salt content of the soil becomes higher and more concentrated. Although there is an abundance of available food in the soil, the cucumber suffers because it is unable to stand a concentrated form of food. Chemical analysis of a normal and an overfed soil throws much light on this important subject. These analyses are given in the accompanying Table 17.

TABLE 17

Average Composition of an Overfed Soil Compared with Normal Soil

	Pounds per Acre	
	Overfed Soil	*Normal Soil*
Total water soluble salts	27.363	7.520
Soluble nitrogen	1.156	444
Soluble potash	6.743	1.328
Soluble phosphoric acid	632	208
Soluble calcium oxide	1.211	864
Soluble sodium oxide	3.259	1.624
Soluble magnesium oxide	966	320
Soluble sulphates	1.240	727

From Table 17 it is seen that an overfed soil has a marked increase of soluble plant food. If we should express this in terms of fertilizers it would make 3¾

tons of nitrate of soda, 6¾ tons of high grade sulphate of potash, 2 tons of 16 per cent. phosphate, and 1 ton of hydrated lime. To express it in terms of a mixed fertilizer it would amount to 14½ tons of a formula testing 4 per cent. nitrogen, 23 per cent. actual potash and 2.25 per cent. available phosphoric acid. The injurious effect on cucumbers is not due to the excess of any one element but rather to the toxicity of the combined excess of soluble salts.

Physiological Wilt

Symptoms. Cucumber growers often find that their plants wilt badly when subjected to the intense rays of the sunlight. This is especially true when bright weather follows a continued cloudy spell. This trouble is common in houses which are poorly ventilated, and where the plants are weak. Too high a temperature and poor lighting will greatly favor wilting. The removal of these causes will effect a cure.

Lack of Color in Fruit

Cucumber fruit, especially of the White Spine variety, often becomes very white, thus commanding a lower market price. This discoloration is probably due to a lack of available nitrogen in the soil. It may be remedied by the application of one part liquid nitrate of soda to one thousand parts of water.

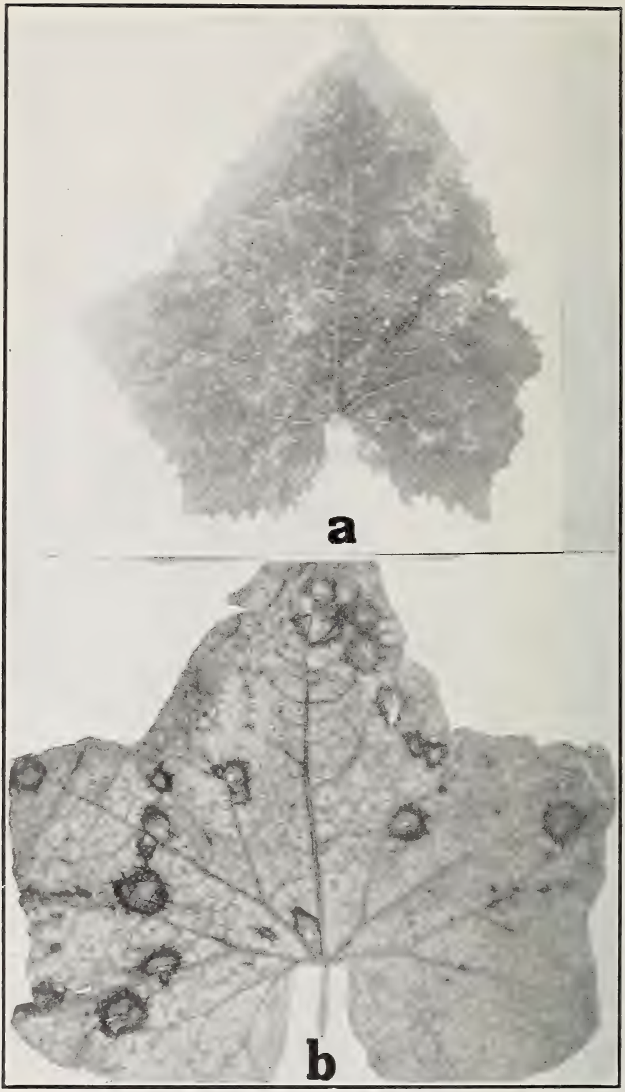

FIG. 21. CUCUMBER DISEASES.
a. Mosaic, *b.* anthracnose.

Mosaic or "White" or "Little Pickle"

Cause unknown.

Symptoms. The first sign appears as a yellow mottling near the stem end of the fruit. Later the light areas are found all over the cucumber, and the darker portions frequently form protuberances. Some fruits retain their green color and show the disease only by being distorted. The leaves become mottled light to dark green (fig. 21, a), and sometimes wrinkled, while the stems and petioles are dwarfed and distorted. Affected leaves die prematurely and are replaced by others, which in turn contract the disease. The trouble is spread principally by the melon louse, *Aphis gossypii* Glov., and to a lesser degree by striped cucumber beetle, *Diabrotica vittata* Fabr. Satisfactory methods of control are still wanting. Affected plants should be destroyed to prevent further spread of the disease.

Bacterial Wilt

Caused by *Bacillus tracheiphillus* Ew. Sm.

The symptoms and the damage caused by this wilt will be found discussed under the muskmelon, p. 155. Recent investigations by Rand and Enlows * have shown that seeds from diseased plants fail to reproduce wilt. This is true not only for the cucumber, but also for all the other cucurbit

* Rand, F. V., and Enlows, E. M. A., U. S. Dept. of Agr. Jour. Agr. Research, 6: 417-434, 1916.

hosts which are subject to this trouble. Of the numerous varieties of cucumber, none shows promise of resistance to the disease.

Angular Leaf Spot

Caused by *Pseudomonas lachrymans* Sm. and Bry.

Symptoms. The trouble is characterized by angular brown spots which tear or drop out when dry, giving a ragged appearance to the infected leaves. In the early stages of the disease a bacterial exudate collects in drops on the lower surface of the spots. This usually dries up and becomes whitish. It seems that angular leaf spots usually attack only the foliage, rarely the fruit.

The Organism. The parasite is a short rod with rounded ends, occurring singly or in pairs with a decided constriction, and occasionally in chains of twelve individuals or more. It is motile by means of polar flagella, produces capsules on agar and milk; no spores, and no gas is formed. The organism completely liquefies gelatine in about three or four weeks. Little is known of methods of control.

Damping Off, see Pythium, p. 28.

Downy Mildew

Caused by *Pseudoperonospora cubensis* (B. and C.) Rost.

Symptoms. The disease appears on the leaves

as yellowish spots, which have no definite outline. In a warm, moist atmosphere numerous spots coalesce, and soon the affected leaves turn yellow and die. With cool temperatures, the spots seem to spread less rapidly. The disease appears to work on the older leaves, beginning on those at the center of the plant and working outwards. With infected plants the center of the hill is clearly marked by a cluster of yellow leaves. Diseased plants may flower profusely, but set no fruit. The few cucumbers which are set are small, deformed, and unfit for the market.

The Organism. The fungus derives its food from the host cells by means of suckers or haustoria. The mycelium is hyaline, non-septate; the conidiophores arise in small clusters through the leaf stomata and are branched and flexuous. The zoosporangia are hyaline but slightly violet, tinted in mass. Germination of zoosporangia is by means of motile zoospores. The zoospores or sexual fruiting stage was first found on the host by Rostovtsev.

Control. Downy mildew seems to be most prevalent on greenhouse cucumbers planted in August. Those set in October seem to be free from it. Where the disease makes its appearance, it is advisable not to syringe the plants, but on the other hand to keep the foliage dry. Diseased plants or parts of plants should be destroyed by fire. Late planting in September or October wherever practicable is also advised.

Timber Rot

Caused by *Sclerotinia libertiana* Fckl.

Symptoms. The disease seems to attack the stem end of the plant nearest to the ground line. Affected stems at first water-soaked, then become invaded with a cushion of white mycelial growth. Rapid wilting, with no recovery, immediately follows. As the affected plant dies, the shriveled stem becomes covered with black masses of fungous bodies, sclerotia. The same fungus also causes lettuce drop. For a description of the causal organism and methods of control, see p. 151.

Powdery Mildew

Caused by *Erysiphe cichoracearum* D. C.

Powdery mildew of cucumbers is not a serious greenhouse trouble. Like all powdery mildews, the causative fungus grows on the surface of the leaf, giving it a white mealy appearance. From the mycelium are produced erect threads which bear the summer spores of the fungus. The ascus or winter stage appears as minute dark-brown, rounded capsules enclosing a group of spore sacs within which are formed the ascospores.

Control. The conditions which favor mildew are overwatering, lack of ventilation, lack of light, and too high a temperature. Proper attention to these factors will help to remove the cause and to effect a cure.

Fig. 22. Cucumber Root Knot.

Anthracnose

Caused by *Colletotrichum lagenarium* (Pass.) Ell. and Hals.

Symptoms. This disease is often serious on greenhouse cucumbers and muskmelons. It is seldom so in the fall and winter, but is most frequently met with in the spring of the year. Affected plants dry up and present a parched appearance. The disease also attacks the cucumber leaves, forming round spots (fig. 21, b.), and on the fruit, deep cankers, thus ruining its market value. It is claimed by practical greenhouse men that the great difference in temperature between day and night, which is unavoidable in the spring when the fires have gone out, favors infection.

The Organism. In structure, *Colletotrichum lagenarium* resembles the organism of bean anthracnose. The cucumber fungus has a peculiar ability to remain dormant during the dry weather; but it is easily revived by moisture. The fruits of the fungus are borne in masses on the pustules which take on a salmon color. The spores are typical of all Colletotrichums—that is, oval, one-celled, and hyaline. The setæ in *C. lagenarium* are not very plentiful. In pure culture it resembles *C. lindemuthianum;* however, pathologically it is distinct from the latter, since numerous attempts by the writer and by others have failed to infect growing bean plants with the watermelon anthracnose or the watermelon with that of the bean.

Control. As soon as the disease makes its appearance the foliage should not be syringed, but kept dry. Spraying with 3-5-50 Bordeaux is recommended.

Root Knot, see Nematode, p. 28 (fig. 22).

Eggplant (*Solanum melongena*)

Cultural Considerations. Eggplants require as much heat as cucumbers. The night temperature should never run down below 60 degrees F. The day temperature may safely be maintained at 80 degrees or more, provided, however, sufficient ventilation is allowed. The best soil for greenhouse eggplants is a light sandy soil containing plenty of organic matter. Raised benches with bottom heat is preferred for winter forcing. The eggplant does not thrive under an excess of water. To obtain marketable fruit, the blossoms must be hand pollinized to insure fertilization.

Diseases of Eggplants

Eggplants are subject to numerous diseases.

Southern Wilt, see Tomato, p. 185.
Damping Off, see Pythium, p. 17.

Fruit Rot

Caused by *Phomosis vexans* (Sacc. and Syd.).

Symptoms. Fruit rot attacks all parts of the plant

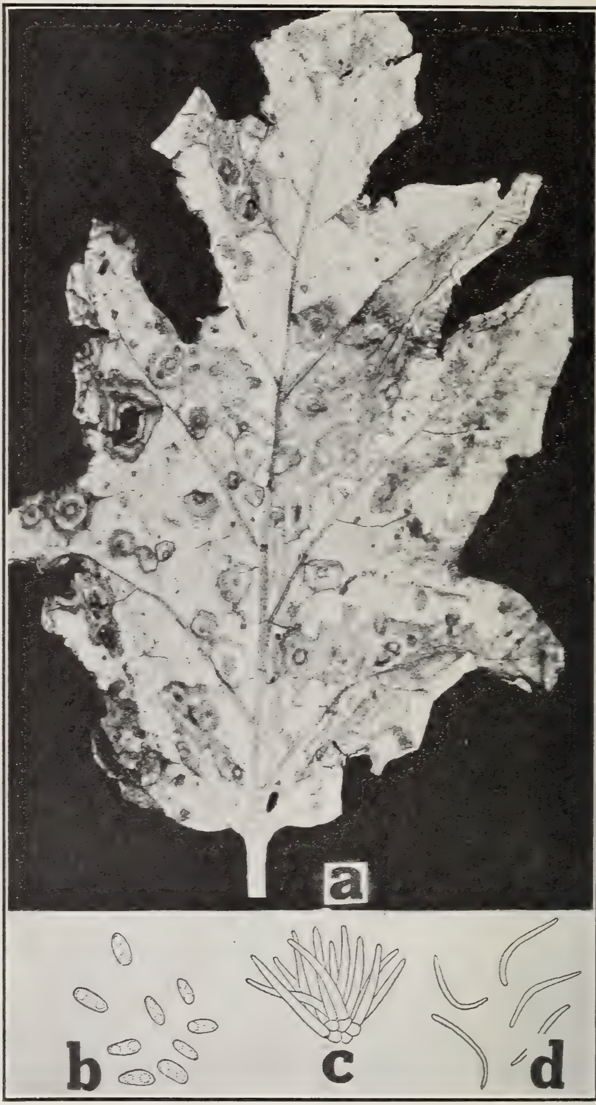

FIG. 23. EGG PLANT DISEASES.

a. Phomosis spot on leaf, *b*. pycniospores, *c*. conidiophores, *d*. stylospores (*b-d* after Harter, L. L.).

except the roots. On the seedlings it causes a damping off. Young plants are attacked at the stem end or an inch or two above the ground line as indicated by a constricted area at that place. On the leaves the trouble is manifested as large brown round spots which later become irregular and ragged (fig. 23, a.). The older spots are light purple in the center and are surrounded by a black margin. As they enlarge the spots also invade the veins, midribs, and petioles, forming depressions. Diseased fruits are at first soft and mushy, but later become dry, shriveled, and mummified (fig. 24, a.).

The Organism. Pycnidia are usually found on all parts of the attacked plant. Within the body of the pycnidia and intermixed with the conidiophores (fig. 23, c.) and pycniospores (fig. 23, b.) are found filiform hooked-shaped bodies termed stylospores (fig. 23, d.). *Phomosis vexans* has been erroneously referred to as *Phoma solani* Hals; *Phoma vexans* Sacc. and Syd., and *Aschochyta hortorum* Speg.

Control. The seedlings in the seed bed should be sprayed with Bordeaux at least once before transplanting. The plant in the house should be sprayed from four to eight times with either Bordeaux mixture or ammoniacal copper carbonate.

Anthracnose

Caused by *Gloesporium melengoneæ* E. and H.

Anthracnose on the eggplant attacks only the

fruit. The trouble is characterized by numerous deep pits which later become covered with salmon colored acervuli (fig. 24, b.). The latter are made up of myriads of spores of the fungus. Spraying for fruit rot will also help to control anthracnose.

Root Knot, see Nematode, p. 28.

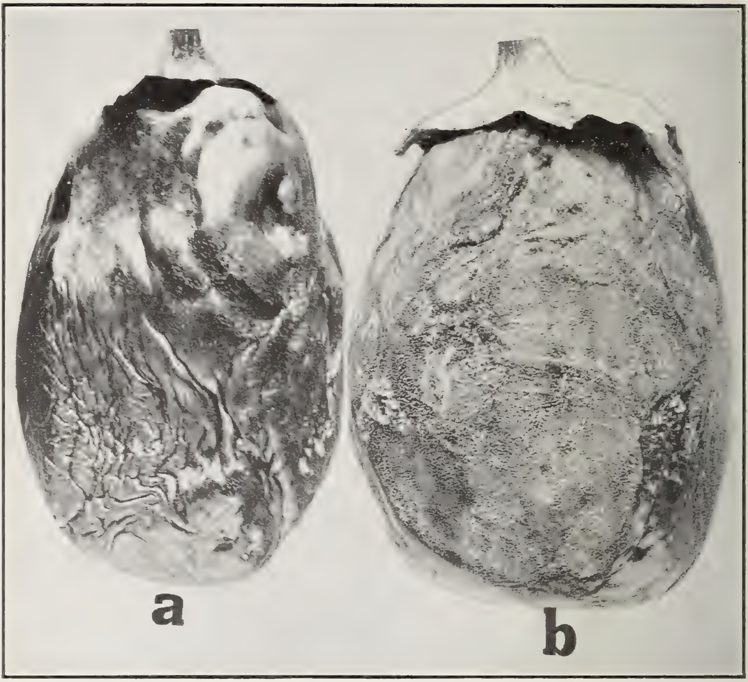

FIG. 24. EGG PLANT DISEASES.
a. Phomosis on fruit, *b.* anthracnose on fruit.

CHAPTER 12

LETTUCE (*Lactuca sativa*)

Cultural Considerations. Lettuce is extensively grown as a greenhouse crop (fig. 25). The best results are obtained where the soil contains considerable sand, especially where head lettuce is produced. This is also true for Coss lettuce. However, the Grand Rapids variety will thrive in any soil. Lettuce is a heavy feeder, hence stable manure is often used exclusively. If the crop does not make rapid headway, nitrate of soda at the rate of one pound to 100 square feet of space may be applied. In using acid phosphate or potash only small quantities should be applied for fear of burning the plants. Lettuce requires an abundance of water and good drainage. High temperatures and humidity will produce weak, spindly plants. Careful ventilation may be the cause of preventing numerous diseases. In mild weather the ventilators may remain open even at night. This, however, should not be done during freezing weather.

It is fortunate that lettuce seed retains its vitality for three or four years. This enables the grower to test out carefully the strains which he uses.

Diseases of Lettuce

Top Burn

Cause, physiological.

Symptoms. In plants suffering from top burn a withering of the leaves is followed by the curling back of the tips and margins of the outer leaves, the affected areas becoming blackened to a distance of an inch or more from the margin. The condition greatly disfigures the lettuce head and reduces its market value.

Causes. The trouble may originate on a bright day following a cloudy spell. The greenhouse air is then saturated with moisture and consequently the lettuce leaves transpire very little. With the sudden appearance of strong sunlight, there is a rise in temperature, and a loss of moisture in the greenhouse air. Under these conditions, the foliage will transpire heavily. If the water given off by the leaves is greater than the roots are able to replace, the leaves will wilt, and if this is continued for any length of time, the tissue along the leaf margin will wither and die.

Control. A practical remedy for top burn is to saturate the greenhouse air with moisture on bright days which follow cloudy spells. This will prevent the undue transpiration of the leaves and its subsequent bad effect.

Fig. 25. Type of Lettuce House.

Bacterial Blight

Caused by *Pseudomonas viridilividum* Br.

Symptoms. The disease seems to attack only the outer leaves of a head. The affected foliage is first covered with numerous watersoaked spots which enlarge, fuse together, and involve the entire area of the affected leaves. The latter either soften or dry up, opening up the way for the entrance of other decay organisms, which may now attack the otherwise sound head.

The Organism is rod-shaped, occurring singly, in pairs, or in chains, and it moves about by means of polar flagella. On agar, the young colonies are round with entire smooth margins; they are translucent, cream white in reflected light, but bluish in transmitted light. The older colonies are not always uniform in color, but may take on yellowish bands or become mottled. The organism does not form gas and it liquefies gelatine slowly. It is not especially sensitive to sunlight.

Control. Since the disease may be introduced with infected soil, soil sterilization is recommended.

The South Carolina Disease

Caused by *Pseudomonas vitans* Br.

Symptoms. The disease may attack the stems or leaves. At first, diseased plants become pale and lose their normal green. Later the head wilts and rots (fig. 26, a.). The rot may be confined to the

outer leaves, or involve the whole head. Affected stems become brittle and may be readily broken. At first they are a blue green afterward becoming brown. The disease is met with in the field, but may also be introduced in the greenhouse.

The Organism. Nellie Brown * has definitely proved that *Pseudomonas vitans* is the cause of the trouble which seems so prevalent in South Carolina. The causal organism is a short rod with rounded ends, motile by means of polar flagella (fig. 26, b.), one at each end; produces no spores, but capsules and pseudozooglœæ. It liquefies gelatin slowly and produces no gas.

Control. The disease may be introduced with infected seedlings or soil. For the latter, soil sterilization with steam or formaldehyde is recommended. Diseased seedlings should be discarded.

The Kansas Disease

Caused by *Pseudomonas marginale* Br.

Symptoms. The disease seems to appear when the plants are half grown. At first the leaves wilt slightly in restricted areas at the margin. On the older leaves wilting starts at the tips. The affected areas fall over and gradually dry up. The vascular tissue then becomes affected and brown, then reddish, and finally black. The tissue of the dead parts on the leaves becomes dry and papery.

* Brown, Nellie A., U. S. Dept. of Agr., Jour. Agr. Research, 13: 367-388, 1918.

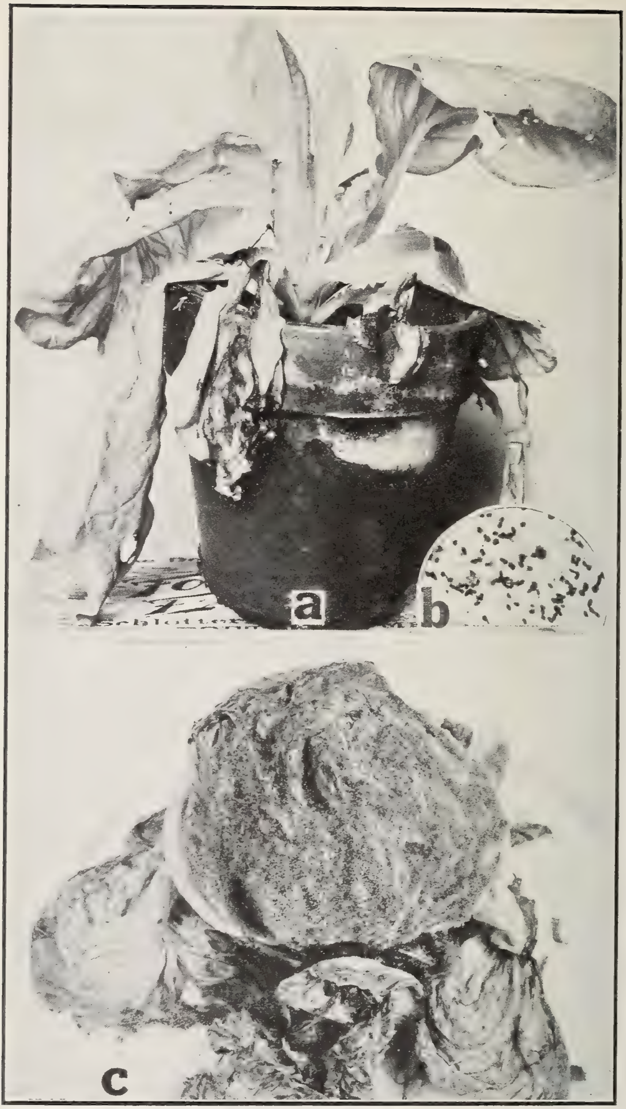

Fig. 26. Lettuce Diseases.

a. Bacterial blight, *b. Pseudomonas vitans,* polar flagella stained with Casares-Gil's stain, *c.* gray mould rot; notice the numerous Botrytis fruiting heads on the wilted lettuce head.

This disease does not cause a rot of the leaves. The trouble is confined mainly to the edges of the foliage, marring the appearance and the market value of the product. The varieties most affected seem to be the Black-seeded Simpson, the Improved Hansen, and the Big Boston. Of the varieties less susceptible may be mentioned the Early Curled Simpson, and Vaughan's All Season. The variety Grand Rapids seems to be immune.

The Organism. Pseudomonas marginale is a short rod, rounded at both ends and motile by means of polar flagella. It forms capsules but no endospores, liquefies gelatin quickly and produces no gas.

Control. Infected material should be destroyed by fire. In watering, splashing should be avoided. Soil sterilization with steam or formaldehyde (see pp. 32-43) is recommended.

Downy Mildew

Caused by *Bremia lactucæ* Reg.

Symptoms. Affected leaves lose their natural green color and turn yellow. A careful examination will disclose a delicate downy web on the under side of the foliage which will have a wilted appearance. The downy web consists of the conidiophores of the fungus. These appear singly and are much branched. The conidia germinate by means of a germ tube. Downy mildew is a disease which is more troublesome in Europe than in the United States, and it is more serious on greenhouse lettuce

than on that grown in the open. In the field it usually attacks fall lettuce. Downy mildew attacks not only lettuce, but also chicory and numerous other Compositæ.

Control. This disease is controlled in the same way as lettuce drop (see p. 151).

GRAY MOLD

Caused by *Sclerotinia fuckeliana* De Bary.

Symptoms. Gray mold attacks grapes in Europe but in the United States it is commonly met with on lettuce plants which are fully developed and somewhat overgrown. The disease is manifested by soft, watersoaked spots on the foliage, causing a wilting. The spots soon become coated with the fruit of a gray mold. The fungus has two stages, the *Botrytis cinera* Pers. stage, which is commonly found as a gray mold on wilted lettuce leaves (fig. 26, c.); the other is the winter or apothecial stage, known as *Sclerotinia fuckeliana.* American botanists have not as yet been able to connect these two forms. It seems, however, that Istvanffi * was able to confirm the work of De Bary, who first indicated the relationship of *Botrytis cinerea* with *Sclerotinia fuckeliana.*

Control, see Lettuce Drop, p. 151.

LETTUCE DROP

Caused by *Sclerotinia libertiana* Fckl.

Symptoms. The term drop best describes the

* Istvanffi, G. De, Ann. de l'institut central ampél. roy. Hongrois: 183-360, 1915.

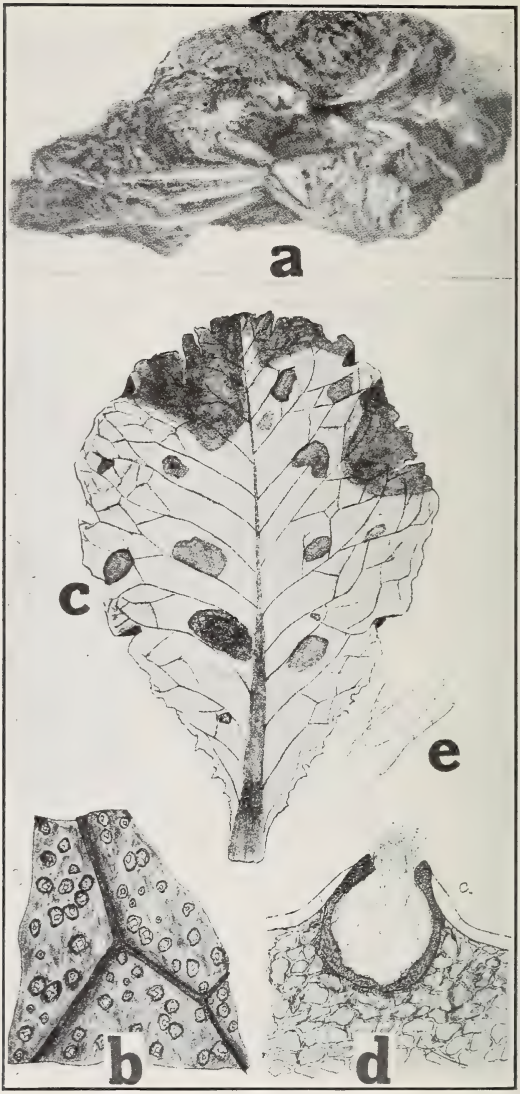

FIG. 27. LETTUCE DISEASES.

a. Drop (after Humphrey), *b.* Septoria leaf spot, *c.* same as *b.* but older spots, *d.* pycnida, *e.* pycniospores (after Selby).

symptoms of the disease. The first sign is a wilting of the lower leaves, which is immediately followed by a drooping of upper ones until the entire plant is involved. The affected plant has a sunken appearance as if scalded with boiling water (fig. 27, a.). In examining a dead plant, a white cottony fungus growth is found on the under side of the lower leaves, and near the moist regions at the stem end.

When the plants are fairly rotted, there appear on the cottony mycelial growth mentioned above, black bodies, or sclerotia, which vary in size from a pinhead to a grain of corn. The three definite symptoms of the disease may be summarized: (1) drooping, (2) cottony-like mycelial growth on the under surface of the affected leaves, (3) the appearance of sclerotia. The latter help to carry over the fungus during the winter. After the sclerotia have been in the soil over winter, they germinate in the following spring by sending out small mushroom-like fruiting bodies known as apothecia. The latter contain small sacs or asci which bear the spores.

Control. Lettuce drop is favored by high temperature, overwatering, and poorly drained beds, leaky roofs, and insufficient ventilation. To check the disease a low night temperature of 50 degrees F. should be maintained. The water should also be withheld and an abundance of ventilation given especially during cloudy weather. Soil sterilization with steam or formaldehyde is also recommended.

Leaf Spot

Caused by *Septoria lactucæ* Pass. and *Septoria consimilis* E. and M.

This disease is induced by two species of Septoria fungi. The symptoms produced by both are so nearly alike that it is difficult to distinguish one from the other, except by microscopic examination. Pale brown discolored spots appear on the older leaves with numerous black pycnidia in the center (fig. 27, b-e.). The disease is of little economic importance, as it usually occurs late in the season, on plants which have nearly passed their usefulness. The Boston variety is considered resistant, while the Salamander and the Wonderful are more susceptible to leaf spot.

Shot Hole

Caused by *Marsonia perforans* E. and E.

The disease is of little economic importance. Affected leaves are covered with dry spots which drop out, leaving irregular perforations. Along the border of these holes, the causative fungus may be found abundantly fruiting. The disease attacks the midribs of the leaves as well as the stem of the plants. It seems to be more prevalent under conditions of surface irrigation.

With sub-irrigation, on the other hand, it is not found to cause any damage.

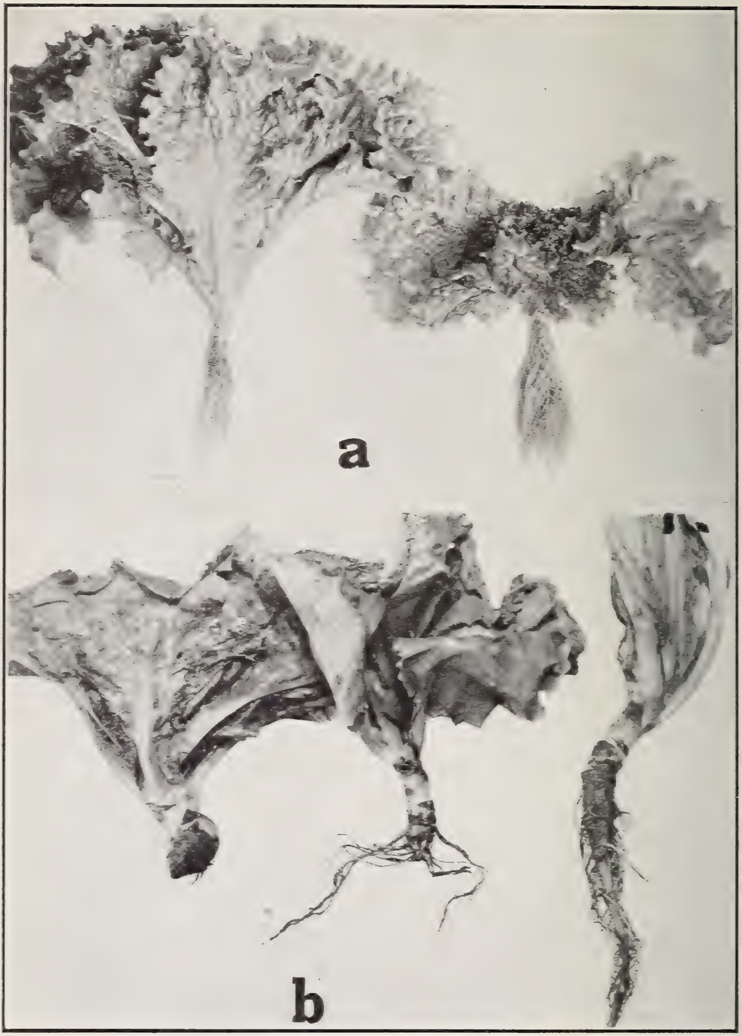

Fig. 28. Lettuce Diseases.

a. Lettuce rosette (to right diseased, and to the left healthy plant), *b*. Rhizoctonia effect on roots; to right healthy roots, to left two diseased ones.

Cercospora Leaf Spot

Caused by *Cercospora lactucæ* Stev.

This disease is as yet of no importance in the United States. The causal fungus attacks the older and lower leaves forming numerous irregular spots.

Rosette

Caused by *Rhizoctonia solani* Kuhn.

Symptoms. The disease attacks young seedlings by causing a damping off. Transplanted seedlings show infection at an early stage. Unlike healthy plants, they fail to send out new leaflets. The general growth takes the form of a rosette. The axis bearing leaf remains stunted. The roots show numerous deep lesions, and in an advanced stage are considerably rotted (fig. 28, b.). For a description of the causal organism, see p. 20, and for methods of control see Lettuce Drop, p. 151.

Root Knot, see Nematode, p. 28.

Mint (*Mentha sp.*)

Cultural Considerations. Mint is often forced on a small scale. The plants are easily grown, and require about the same indoor conditions as the lettuce.

Diseases of the Mint

Indoor mint may be subject to but one disease of importance.

Rust

Caused by *Puccinia menthæ* Pers.

This disease attacks about thirty-five members of the mint family. All the three stages of the fungus, *i.e.*, æcidiospores, uredospores, and teleutospores, occur on the same host. The disease is characterized by brown sori which are at first cinnamon colored and later become chestnut brown. Diseased leaves curl and dry up. The infected parts of plants should be destroyed by fire.

Muskmelon (*Cucumis melo*)

Cultural Considerations. Muskmelon culture is little different from that of the cucumber (fig. 29.). However, the former is very sensitive to cold drafts and sudden changes in temperatures. For forcing, the heavier types of soil seem to be more desirable than the lighter ones. The fertilizer requirements for muskmelons are practically the same as those for cucumbers. Muskmelons require an abundance of soil moisture, but are sensitive to overwatering. It is also essential to maintain a high humidity in the house during the period of active growth. During pollination and the ripening of the fruit the above condition is unnecessary. The temperature should be about 70 to 75 degrees F. at night and from 80 to 85 degrees Fahrenheit during the day. Muskmelons, like cucumber blossoms, must be pollinated artificially, since both male and female flow-

FIG. 29.
Typical muskmelon house, showing method of trailing and supporting fruit.

ers are distinct. The pollination is done by means of a camel's-hair brush, where the pollen from the male blossoms is rubbed on the stigma of the female flowers.

Diseases of the Muskmelon

Like cucumbers, greenhouse muskmelons are subject to numerous diseases.

Bacterial Wilt

Caused by *Bacillus tracheiphillus* Ew. Sm.

Symptoms. The symptoms of bacterial wilt are very striking. At first a few leaves of the plant are wilted. Soon after, the entire plant wilts and dies. Upon cutting through an infected stem, one observes a whitish viscid exudate that oozes out from the vascular bundles of the cut surface. If one places his finger on the viscid substance and then gently removes it, the bacteria will be strung out into numerous delicate threads resembling cobwebs. The disease works quickly, and the change of leaf color from bright to dull green is also sudden. Muskmelons, unlike squash, show no tendency to recover temporarily from wilt.

Bacterial wilt is spread about through the bites of leaf-eating beetles, such as striped cucumber beetle (*Diabrotica vittata*).

The Organism. B. tracheiphilus is a short straight rod with rounded ends. The organism occurs singly, in pairs, or rarely in chains of four; it is

motile by means of flagella. It grows slowly on gelatine which is not liquefied. On potato cylinders growth is vigorous, resulting in a gray-white film with no changes manifested in the substratum. There is no gas production and the organism is aërobic.

Control. Infection begins at a place of injury that has been produced by the bite or puncture of insects. Hence, any attempt to control wilt should first aim to control insect pests (see pp. 381-410).

DOWNY MILDEW, see Cucumber, p. 138.

POWDERY MILDEW

Caused by *Erysiphe polygoni* D. C.

This disease is the same as the mildew which attacks cucumbers and numerous other hosts. Mildew is prevalent on greenhouse melons. It is characterized by powdery white patches on the leaves. For control, see p. 323.

MYCOSPHÆRELLA WILT

Caused by *Mycosphærella citrullina* (Sm.) Gr.

Symptoms. This form of wilt is often a serious greenhouse trouble. Grossenbacher * found that infection is localized at the nodes and not at the internodes. The injury from Red Spider or from other sucking insects is perhaps responsible for opening

* Grossenbacher, J. G., New York (Geneva) Agr. Expt. Sta. Tech. Bul. 9: 197-229, 1909.

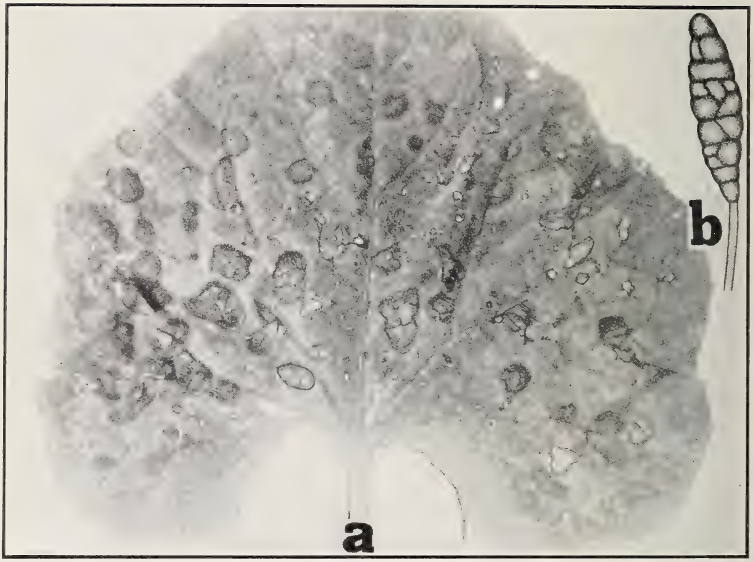

Fig. 30. Muskmelon Diseases.
a. Alternaria leaf spot, *b.* Alternaria spore (after Schwarze).

the way to this disease. A characteristic of the trouble is that the edges of the infected areas are covered with an oily, green to raisin-colored gum. The older parts of the spots are either dark and gummy or gray and dry, bearing numerous brown pycnidia.

The Organism. The perithecia are roundish, rough, dark brown to black, and almost superficial on the surface of the spots. The necks of the perithecia are hairy, the ascospores are cylindrical, two-celled, hyaline, and slightly constricted at the center.

Control. Spraying with Bordeaux mixtures when the plants are about half grown and before the disease appears is recommended. Spraying should be continued so that the growing parts are kept covered with the fungicide.

ANTHRACNOSE, see Cucumber, p. 141.

LEAF BLIGHT

Caused by *Alternaria brassicæ* var. *nigrescens* Pegl.

Symptoms. The disease begins as small round spots which gradually enlarge. These spots are dry, brown in color and made up of concentric rings or zones (fig. 30, a and b.). Usually the spots are very numerous and their presence causes the leaves to curl and dry up prematurely, leaving bare vines and unprotected fruit. As a result, the melons ripen early and have an insipid taste, and are very poor shippers. Leaf blight is most serious under field conditions.

Control. The disease may be kept in check by spraying with a weak solution of Bordeaux mixture.

Southern Blight

Caused by *Sclerotium rolfsii* Sacc.

Southern blight, a disease that attacks a large variety of hosts, is a serious melon disease in the Southern States. The injury in most cases is confined to the foot of the stem, the girdling and rotting of which finally causes the death of the affected plant. In the case of the cantaloupe, the fruit itself is attacked, infection usually taking place at a point where it touches the ground. The disease appears first as a slight soft spot which enlarges quickly, changing the entire mass of the fruit to a mushy pulp. The exterior of the affected melon is rapidly covered with a white cottony growth consisting of the mycelium of the fungus. Later there appear numerous whitish bodies known as sclerotia which turn yellowish and then brown. They help to carry the fungus over the winter. For methods of control, see pp. 32-43.

Root Knot, see Nematode, p. 28 (fig. 31).

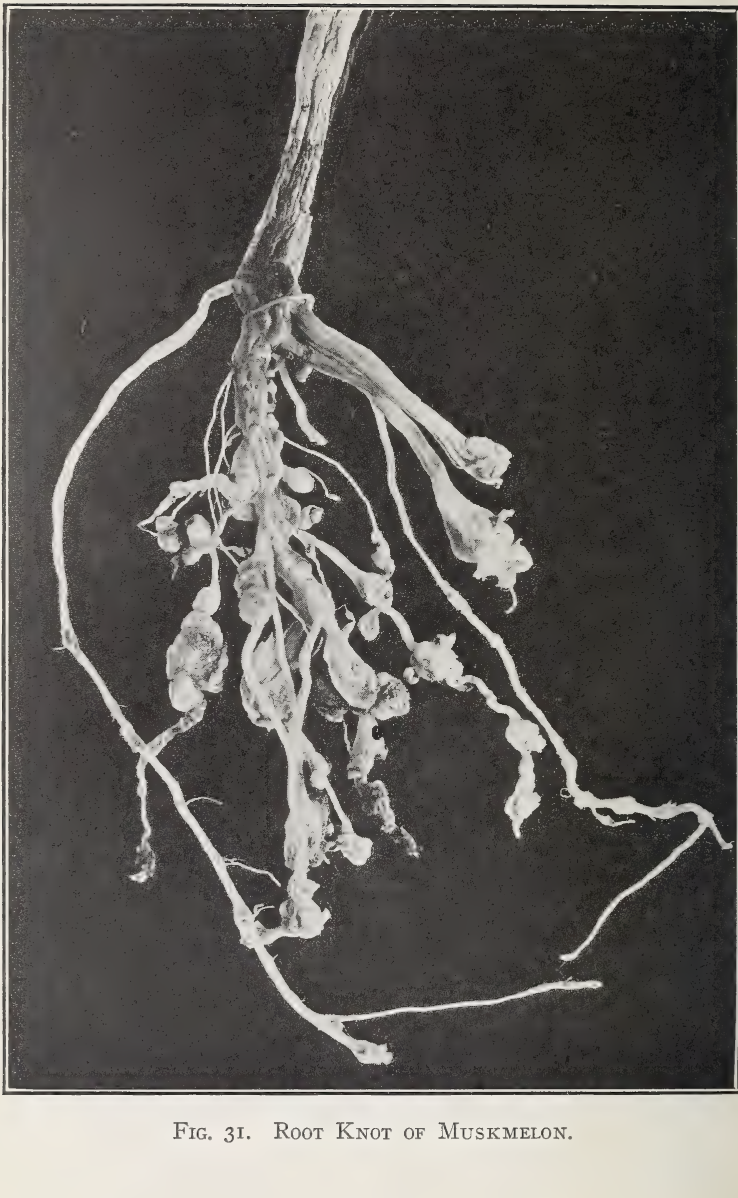

Fig. 31. Root Knot of Muskmelon.

CHAPTER 13

THE MUSHROOM, *Agaricus campestris L.*

Cultural Considerations. As a rule florists are not as yet giving the mushroom the attention and consideration which it deserves. It is a crop which adapts itself particularly well to growth under benches, so that it utilizes all the extra greenhouse space (fig. 32, a and b.). Like all other remunerative crops, it requires skill to insure its permanent success.

Temperature. Mushrooms may be grown in tomato houses. In this case, the day temperature should run from 60° to 70° F. and the night temperature about 55° F. It should never be allowed to fall below 50 degrees. At less than 50° the crop does not thrive, although the spawn in the soil may endure freezing temperature without being killed.

Preparation of Soil. In preparing the soil, fresh horse manure is mixed with loam as follows: To three shovelfuls of manure add one of loam, piled alternately in thin layers. This is kept for three days, but mixed every day in order to prevent the rapid fermentation or heating. This mixing is continued until all danger of spontaneous combustion

is over. At this stage, the manure loses its rank odor and is ready to be put in the bed.

Preparation of the Beds. The beds should be located preferably under the center benches, and inclosed in rough boards eight inches wide and one inch thick. The boards are set on edge and raised slightly above the floor so that with a bed ten inches thick the top of the bed would not extend much above the upper edge of the board. A layer of prepared manure is then spread evenly over the bottom of the bed, to the depth of three inches, and firmly pressed down by pounding with a brick. Two other layers of manure, each three inches thick and firmly pressed down are laid on the first, making the bottom about eight inches thick. A thermometer is placed in the manure and the temperature watched until it registers about 90 degrees F.

Spawning the Bed. When the temperature of the manure in the bed ceases to rise above 90 degrees, it is ready to be planted with the spawn. The latter is usually bought in bricks, sixteen of which make a bushel. Each brick is broken into twelve equal parts, which are inserted about an inch deep in the manure bed with intervals of nine inches. The manure is then packed firmly over the pieces, leaving the surface of the bed smooth again. Two weeks after planting the spawn, the beds are coated with two inches of the mellow loam prepared as stated above. The loam should be neither dry nor wet, but simply moist. It should not be applied until it is certain that the spawn has commenced

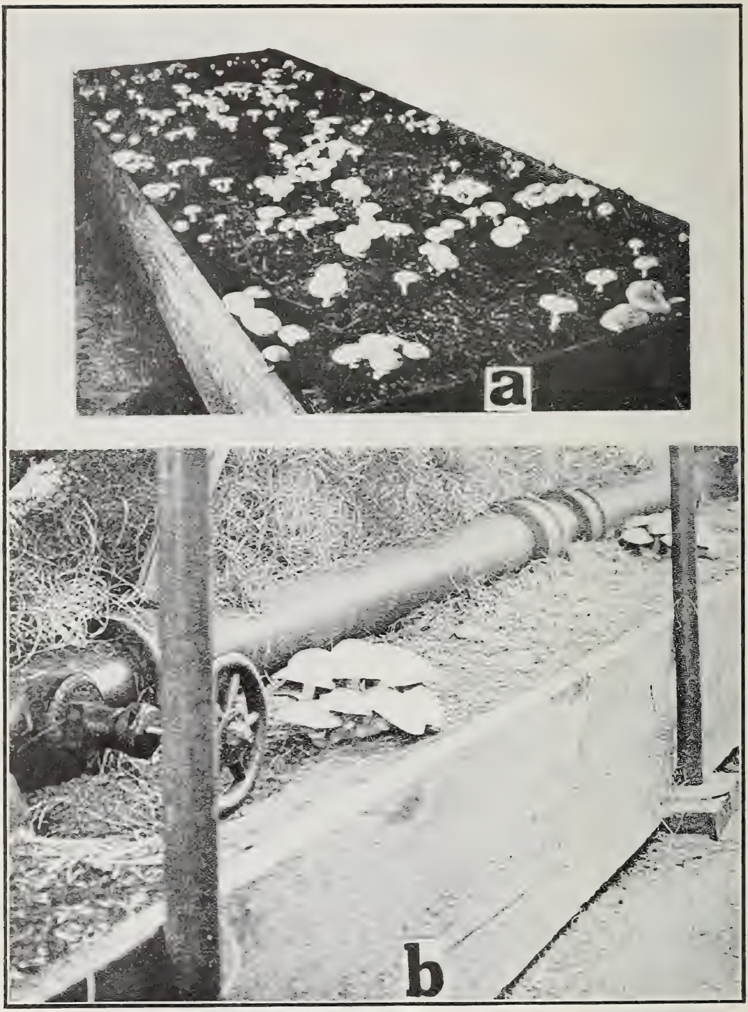

Fig. 32.

a. Healthy mushroom bed, *b.* mushrooms grown under the benches in the greenhouse (after Beach and Paddock).

growing. This becomes noticeable as a bluish-white, moldy growth. The loam beds should be covered with a three-inch layer of excelsior to keep them from drying. The mushroom beds should be protected from the drippings of the overhead benches by a roof of heavy waterproof cover.

Watering. Care should be taken never to overwater the beds. It is necessary to apply enough water to keep the surface of the bed moist, but not soaked. In watering the excelsior is often rolled back or else water may be applied on top of it. Beach* recommends as the beds begin to bear that they be watered twice a week with nitrate of soda dissolved at the rate of one ounce to each gallon of water. It is applied with a watering can in a quantity sufficient to moisten, but not to soak the beds. To promote good bearing and to prevent a rapid exhaustion, the beds are often coated over again with a layer one and a half inches thick of fine mellow loam.

Diseases of the Mushroom

Mushrooms are subject to few diseases. There are but two which need concern the greenhouse man.

Bacterial Spot

Caused by *Pseudomonas fluorescens* (Fl.) Mig.

This disease, although serious, seems to be re-

* Beach, S. A., New York (Geneva) Agr. Expt. Sta. Fourteenth Ann. Rept.: 331-341, 1895.

stricted as yet to the mushroom caves in St. Paul, Minnesota. The trouble was first described by Tolaas.*

Symptoms. It is characterized by an unsightly spotting of the caps, the severity of which differs in the cultivated varieties, especially the large white kinds. The spots, which do not extend deep into the flesh, appear while the mushroom is in the button stage, or when the cap is fully expanded. The spots are at first pale yellow, but later become a chocolate brown. Though the disease does not seem to reduce the yield, the market value of the spotted mushrooms is considerably reduced.

The Organism. Pseudomonas fluorescens is a small rod rounded at both ends and motile by means of polar flagella. It is a facultative anaërobe; produces no endospores, no gas, but liquefies gelatine. On beef and potato agar, it produces a shiny grayish white growth accompanied by a greenish pigmentation, which diffuses in the substratum.

Control. Spraying the mushroom caps with solutions of benetol, sodium carbonate, or copper sulphate seems to have no beneficial effect. On the other hand, fumigating the beds with sulphur before planting the spawn insures the production later of a clean crop of mushrooms. The amount of sulphur to use is about one and a half pounds to each thousand cubic feet of house space.

*Tolaas, A. S., Phytopath. 5: 51-53, 1915.

The Mycogone Disease

Caused by *Mycogone perniciosa* Mag.

The Mycogone is a very destructive mushroom disease. The exact amount of its distribution in the United States is as yet unknown. However, if once introduced in a house, it is likely to ruin the entire crop.

Symptoms. The symptoms of the disease are often various. The presence of the malady may be indicated by small tubercules on the cap and by a form of fluffy white growth on the gills, which interferes with their normal development. The result is distorted caps and stipes, and finally, a general darkening and decay of the tissue. In severe cases, monstrous soft masses with thick white fungus coatings are observed in houses in which the disease is very prevalent. In this case, the affected plants have little resemblance to mushrooms. They decay rapidly, and emit a very disagreeable odor.

The Organism. The spores of Mycogone perniciosa are very characteristic. They consist of two cells, the upper spherical, rough, and covered with warts, the lower hyaline and smooth. Both cells possess thick walls.

Control. According to Veihmeyer,* there are no evidences that tend to show that the Mycogone disease is carried with the spawn manufactured by the "tissue culture" method. It is very probable, however, that the disease was introduced into this coun-

*Veihmeyer, F. J., U. S. Dept. of Agr. Bul. 127: 1-24, 1914.

try from France with imported virgin spawn collected at random from fields. The disease may be introduced into a new place with the manure and then spread quickly in a number of ways. Immediate precautionary measures are essential for the control of this trouble. Diseased plants when first noticed should be pulled out and burnt. Allowing these infected plants to decay in the beds is a sure means of spreading the fungus broadcast. The gain from keeping the beds free from diseased specimens will more than compensate for the trouble. At the end of the season the soil in beds should be carried away to a distance where mushrooms will not be grown, although it may be used for garden purposes, since the Mycogone disease is known to attack only mushrooms. After the house has been thoroughly cleaned out, it should be disinfected with the formaldehyde gas method. This is carried out as follows: For every thousand cubic feet of house space use three pints of formaldehyde and twenty-three ounces of potassium permanganate. The potassium permanganate is placed in two or three earthen or wooden vessels, each having a capacity of one quart to every ounce of permanganate. When ready for the operation, the mushroom house is sprinkled with water, the potassium permanganate placed in the receptacles, the formaldehyde is poured evenly over the permanganate, and the greenhouse doors are closed at once. They are kept closed for twenty-four hours and then opened to allow the formaldehyde fumes to escape. All lights must be kept away from the house

while they are being fumigated since formaldehyde gas explodes upon coming in contact with fire. Mushroom houses thus treated may be thoroughly rid of the Mycogone disease, but care must be taken to prevent reinfection.

It is hardly necessary to add that all tools and wagons which were used in connection with the infected houses should be disinfected before being used again. All such tools and vehicles should be washed in a solution of one pint of formaldehyde in twenty gallons of water. Throughout the process the operator must exercise extreme care not to inhale any of the poisonous formaldehyde fumes.

CHAPTER 14

PARSLEY (*Carum petroselinum*)

Cultural Considerations. Parsley is easily forced and requires no particular care. Any of the curly-leaved varieties lend themselves to forcing.

DISEASES OF PARSLEY

Under greenhouse conditions parsley is subject to but few diseases.

DROP, see Lettuce, p. 150.

LATE BLIGHT, see Celery, p. 130.

PEA (*Pisum sativum*)

Cultural Considerations. Peas are seldom forced, although they could be easily grown in the greenhouse. No attempt should be made to grow them after March. They require a night temperature of 40 to 50 degrees F. and a day temperature of about 60 degrees. They are readily injured by higher temperatures. They thrive best in solid beds and require an abundance of water and good drainage. The early dwarf varieties lend themselves well to forcing.

Fig. 33. Sclerotinia Rot on Pea Pods.

Diseases of the Pea

Indoor peas may become subject to several diseases.

Sclerotinia rot (fig. 33), see Lettuce drop, p. 150.

Thielavia Root Rot

Caused by *Thielavia basicola* Zopf.

Symptoms. Plants severely infected with Thielavia have practically no root system, for the latter is destroyed by the fungus as rapidly as they are formed. All that is left is a charred, blackened stub. The diseased host constantly attempts to produce new roots above the injured part, but these in turn become infected. Such plants linger for a long time, but fail to set pods which are of any value.

The Organism. The mycelium of *Thielavia basicola* is hyaline, septate, and branched. The Mycelium becomes somewhat gray with age. Three kinds of spore forms are produced—endospores, chlamydospores, and ascospores. The endospores are so called because they are formed inside a special thread of the mycelium. This is the spore form that commonly occurs in pure cultures of artificial media and on the host. The endospore case is formed on terminal branches with a somewhat swollen base and a long tapering cell. The endospores are formed in the apex of this terminal cell and are pushed out of the ruptured end by the growth of the unfrag-

mented protoplasm of the base. They are hyaline, thin walled, and vary from oblong to linear in shape. The chlamydospores are thick walled, dark brown bodies borne on the same mycelium as the endospores. This type of spore is formed in great abundance on the host and particularly within the affected tissue. The ascospores are lenticular in shape and are borne in asci or sacs within black perithecia. This stage, however, has not been found on the pea nor in pure culture.

Control. Since the causal organism is introduced with infected manure or soil, sterilizing the beds with steam or formaldehyde (see pp. 32-43) is recommended.

Powdery Mildew, see Bean, p. 111.

Pod Spot

Caused by *Sphærella pinodes* (Berk. and Bl.) Niessl.

Symptoms. On the stem the trouble appears as numerous elongated lesions. These spread to such an extent as actually to girdle the affected stem. On the leaves are formed oval spots, grayish in the center, and limited by a dark band. The pods, too, become badly attacked and the symptoms there resemble those on the stems. The disease works its way from the pods to the seed within.

The Organism. The causative fungus has two spore stages. The pycnidia bear the hyaline, two-celled spores, and are formed within the dead tissue

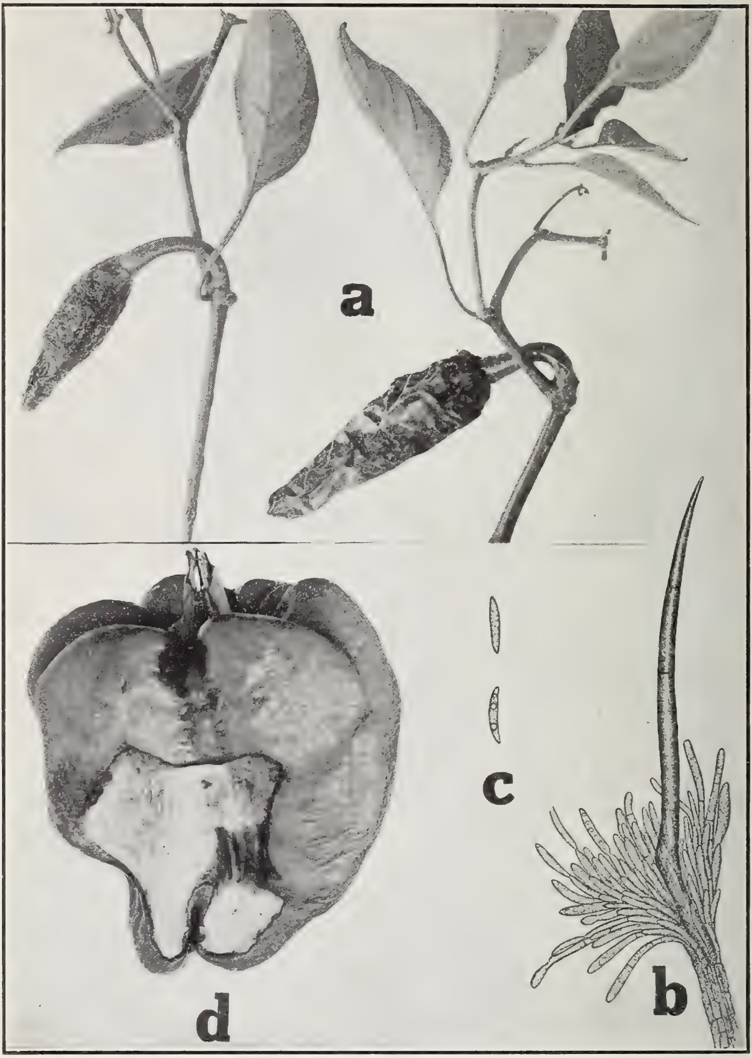

FIG. 34. PEPPER DISEASES.

a. Anthracnose, *b.* part of ascervulis, showing seteæ, *c.* anthracnose spores of *Colletotrichum nigrum* (*b-c* after Schwarze), *d.* sunburn.

of the affected stems, leaves, or pods. The pycnidial stage is known as *Ascochyta pisi* Lib. The winter or ascospore stage has only recently been discovered by Stone,* who found it on pods and stems previously affected, and on culture media. The fungus may be carried from year to year as dormant mycelium within the seed, or in the ascospore stage.

Control. Seed treatment will not be of any value since the fungus is hidden within the seed. No outside treatment is capable of reaching the parasite within. Seed should be secured from localities known to be free from the disease. Susceptible varieties, such as French June, Market Garden, American Wonder, should be discarded. The Alaska variety is said to be more resistant.

Pepper (*Capsicum annum*).

Cultural Considerations. Peppers are not difficult to force, although they are not extensively grown on a commercial scale in the greenhouse. Peppers thrive best at a temperature slightly lower than that required by cucumbers (see p. 133). The Sweet Mountain variety seems to lend itself best to forcing.

Diseases of the Pepper

The pepper plant is considered comparatively hardy, and its few diseases usually become troublesome only when the crop is neglected.

Sun Burn (fig. 34, d), see p. 94.

*Stone, R. E., Annales Mycol., 10: 564-592, 1912.

Anthracnose

Caused by *Glomerella piperata* (E. and E.) S.

Anthracnose is a serious disease which is usually confined to the fruit. Its symptoms are characterized by round, soft, sunken, pale spots (fig. 34, a). The summer or conidial stage is known as *Gleosporium piperatum* E. and E. and is found as salmon colored pustules abundantly scattered over the spots. The ascospore stage may develop in pure cultures of the fungus.

Black Anthracnose

Caused by *Colletotrichum nigrum* E. and H.

This form of anthracnose differs from the disease described above only in that the spots turn jet black. The trouble attacks the young as well as the mature fruit. The winter or ascospore stage of the causative fungus has not as yet been found. It is very probable that the fungus (fig. 34, b-c) is carried over as viable mycelium on the infected fruit left over in the field. Both forms of anthracnose may be controlled by spraying with Bordeaux mixture.

Fruit Spot

Caused by Macrosporium sp.

This disease, which is as important as anthracnose, attacks the fruit at the blossom end. The peppers that are attacked are half rotted, black, and moldy.

Little is known about the causative fungus. It is probable that the disease has the same origin as the blossom end rot of tomatoes, and that the Macrosporium fungus is only secondary. Spraying with Bordeaux mixture is recommended.

Leaf Spot

Caused by *Cercospora capsisi* H. and W.

This disease is characterized by roundish raised spots on the upper surface, at first brown, later becoming gray brown. They are limited by a dark zone, beyond which the leaf tissue is pale and chlorotic. Where the spots are abundant the leaves turn yellow, wilt, and fall off prematurely.

The conidiophores of the fungus are formed in clusters on both surfaces of the spots. The conidia are dilutely brown, clavate, and several septate. As a control measure spraying with Bordeaux mixture is recommended.

Southern Blight

Caused by *Sclerotium rolfsii* Sacc.

Symptoms. Affected plants show a drooping of the young leaves at the tips of the branches. At night the plant seems to recover and it appears normal the next morning. This recovery, however, is only temporary. Wilting generally follows, and after three or four days the leaves become completely yellow, wilt, droop, and die. In another day, the

stem of the plant loses its green color, dries up, and dies. On pulling out a plant freshly wilted, we find a shrunken discolored area at the foot of the stem, slightly below ground level. In more advanced stages, the shrunken area is covered by a delicate web of white mycelial threads, and after the death of the plant numerous brown mustardlike sclerotia are found on the surface of the affected tissue.

Control. The causal fungus is introduced in the greenhouse with infected soil or manure. Soil sterilization with steam or formaldehyde (see pp. 32-43) is recommended.

CHAPTER 15

RADISH (*Raphnus sativus*)

Cultural Considerations. There are few greenhouses near a large city which do not force radishes. The radish more than any other plant thrives best in full light. Shade favors the development of foliage over root. The varieties best liked by the market are those of the Scarlet Rose type. A light sandy soil which contains sufficient humus is ideal for forced radishes. Radishes need plenty of water. However, overwatering may favor damping off. The most favorable temperatures are 43 to 45 degrees F. at night and about 55 to 62 degrees during the day. In warm days the ventilators should be fully open. On cold days they may be opened a little at a time. Radishes are often intercropped with lettuce or cauliflower.

Diseases of the Radish

Radish is subject to many diseases in common with the cauliflower and numerous other crucifers.

Club Root, see Cauliflower, p. 122.

Black Rot

Caused by *Pseudomonas campestris* (Pam.) Ew. Sm.

Symptoms. Black rot on radish is confined mostly to the tender white-rooted varieties, especially the Icicle. The black-rot germ penetrates the lateral feeding rootlets, from which it works its way into the main root. In cutting across a diseased radish, its interior fibrovascular bundles are found to be blackened. Such radishes are useless for the market. The disease seldom attacks the red or the black-skinned varieties. For further consideration see Black Rot, p. 124.

Scab

Caused by *Actinomyces chromogenus* Gasp.

Scab is not a common field disease of radishes. It is, however, found to be troublesome on the crop grown in greenhouses. The French Breakfast variety is commonly susceptible to the disease. The trouble may be expected if the crop is planted in a soil which previously produced a potato crop that was badly scabbed or where infected manure was used, or too much lime applied. For methods of control, soil sterilization with steam or formaldehyde is recommended (see pp. 32-43).

Damping Off

Caused by *Rheosporangium asphanidermatum* Ed.

Symptoms. The disease seldom attacks the leaves. The injury is confined to the roots only. Diseased plants are flabby, pale or yellowish, with a tendency to wilt. The roots when pulled out will show that

Fig. 35. Rheosporangium Rot of Radish.

the rootlets have been rotted off and that the main root, too, has rotted at various intervals * (fig. 35).

Control. This disease may be controlled in the same way as damping off (see pp. 32-43).

Downy Mildew, see Cauliflower, p. 127.

Damping Off, see Rhizoctonia, p. 20.

Root Knot, see Nematode, p. 28.

Rhubarb

Cultural Considerations. Rhubarb is a popular greenhouse crop, and is extensively forced for winter use. Greenhouse rhubarb is superior in quality and in texture to the out-of-doors variety. The plant may grow in total darkness, but a diffused dim light is advisable. The roots before being planted should be thoroughly frozen for a few days, then given a short rest. In the milder climates of the South, the roots should be dried before planting. Both of these treatments will accelerate growth. When well established the plants need not be watered more than twice a week. The temperature for rapid growth ranges from 50 to 55 or 60 degrees F. Under lower temperatures, the plants will require a longer time to mature. The varieties which lend themselves well to forcing are the Paragon, Mammoth, Linnæus, Strawberry, and Victoria.

* A description of the causal organism is given in the author's previous volume, "Diseases of Truck Crops and their Control," p. 210, 1918. (E. P. Dutton & Co., New York.)

Diseases of the Rhubarb

The Rhubarb is considered a very hardy plant. It is subject to but few diseases.

Powdery Mildew

Caused by *Peronospora jaapiana* Mag.

This disease is fairly prevalent in Europe. Its presence in the United States is not definitely known. At any rate it is of little economic importance.

Rust

Caused by *Puccinia phragmitis* Schum.

Rust is a disease of little consequence. The æcium known as *Æcidium rubellum* occurs on the rhubarb. The uredinia and the telia are found on Phragmitis. By destroying the Phragmitis the rhubarb rust will be prevented.

Anthracnose

Caused by *Vermicularia polygoni-virginica* Schw.

This disease is frequently found on old leaves of rhubarb grown out of doors. It is of little economic importance.

Leaf Spot

Caused by *Ascochyta rhei* E. and E.

Like anthracnose, this trouble is of little impor-

tance to greenhouse rhubarb. The causal fungus causes irregular spots, which fall out and give the affected foliage a ragged appearance.

SPINACH (*Spinacia oleracea*)

Cultural Considerations. There has developed lately a tendency to grow indoor spinach on a large scale. Growers who have tried it out find that it is as profitable a crop as lettuce. The cultural requirements of spinach are the same as those of lettuce, see p. 145. If the soil is deficient in nitrogen an application of nitrate of soda will be very beneficial. The aim should be to encourage rapid growth, which, moreover, insures high quality. Vigorous broad-leaved varieties such as Victoria, New Zealand, and others are recommended.

DISEASES OF THE SPINACH

Indoor spinach is generally subject to less diseases than that grown out of doors.

MALNUTRITION

Cause: An excess of acidity or a lack of soil humus.

Symptoms. Malnutrition may be met with where commercial fertilizers are used to the exclusion of organic manures. The margins of the veins of the leaves become yellow while the central part takes on a mottled appearance. The outer leaves are usu-

ally the first to suffer; soon, however, the entire plant exhibits similar symptoms and ceases to grow.

Control. Where this disease is prevalent, the soil should be changed, or sufficient organic matter in the form of well rotted manure incorporated in the beds. Malnutrition as a rule is not prevalent in the greenhouse, for it is rare that a greenhouse soil is lacking in humus.

Downy Mildew

Caused by *Peronospora effusa* Rabenh.

Symptoms. The trouble is characterized by yellow spots of conspicuous size on the upper part of the leaves. On the under side of the leaves, and corresponding to the spots above, is seen a mat composed of the dirty white or violet gray fruiting bodies of the fungus. The disease is often prevalent in the field.

The Organism. Downy mildew is caused by the fungus *Peronospora effusa.* The spores of the parasite are borne on branches, which generally emerge through the breathing pores or stomata of the lower part of the leaf and germinate by sending out a slender germ tube. Infection takes place when the germ tube penetrates the upper side of the leaf, generally through the stomata. The winter stage or oospores may be found in the affected leaves.

Control. All infected material should be destroyed. Water should be withheld, and plenty

of ventilation allowed whenever possible. The plants may be sprayed with a standard fungicide.

Anthracnose

Caused by *Colletotrichum spinaciæ* Ell. and Hals.

Symptoms. It appears as minute, round, water-soaked spots on the leaves. These quickly enlarge and become gray and dry. In the spots will be found evenly-scattered, minute, dark tufts; these are merely fruiting pustules which also contain minute black bristles or setæ. The disease is not limited to any particular part of the plant. Infection may take place anywhere on the foliage, stems, or petioles. The spore pustules may be formed on the upper as well as on the lower surface of the leaf. Under moist conditions, the pustules take on a salmon tinge, indicating that there is an abundance of spores formed at that time. The spores may be carried from leaf to leaf and from plant to plant by insects, wind, or rain water. In badly infected beds, picking should not be done when the leaves are wet. Infected material should be destroyed by fire.

The fungi *Entyloma ellissii* Hals, *Phyllosticta chenopodii* Sacc., *Cladosporium macrocarpum* Preuss, and *Heterosporium variabile* Cke. do not seem to trouble indoor spinach but are rather serious out of doors.

CHAPTER 16

TOMATO (*Lycopersicum esculentum*)

Cultural Considerations. The tomato is one of the three most important greenhouse vegetables. It is perhaps more difficult to grow than either lettuce or cucumbers. Great skill is required in the heating, watering, ventilating, and pollinating. To overlook any of these factors may result in failure. Of the numerous varieties which lend themselves to forcing the following are the most preferred by the American and English growers:

American Varieties	*English Varieties*
Beauty	Best of All
Bonny Best	Carter's Sunrise
Earliana	Comet
Magnus	Frogmare
Stone	Globe
	Lorillard
	Peerless
	Sterling Castle.

The tomato thrives best in a medium heavy loam. The plants are heavy feeders. The fertilizer must be well balanced mixtures. The nitrogen, for instance, should not take the place of the potash or

the phosphoric acid. Tomato plants require a liberal supply of water. However, overwatering will encourage numerous diseases. On bright, sunny days there is little danger of overwatering, but great care is required not to overwater during cloudy weather.

The temperature for greenhouse tomatoes is very important. At night and on cloudy days it should be maintained at about 60 degrees F. During bright, sunny days higher temperatures will not be harmful. The house should be given all the ventilation possible. Even during cold days, the ventilators should be opened slightly at frequent intervals while a close watch should be kept on the indoor thermometer.

Diseases of Tomatoes

Greenhouse tomatoes are subject to a large number of diseases. Many of these are of economic importance.

Hollow Stem

Cause, physiological.

Symptoms. Hollow stem is a trouble manifested by seedlings in the bed, or after transplanting. The central portion of the head of the plant remains green while the lower leaves turn yellow. In severe cases, affected plants fall over as in damping off, with the absence, however, of signs of rotting.

Such plants when examined are found to have hollow stems and seem too weak to stand up.

Cause. There are several causes, any one or all of which may lead up to hollow stem. (1) A highly nitrogenous fertilizer applied to the seed bed to force the seedlings. (2) An abundance of water supply to make the fertilizer quickly available. (3) Sowing seeds of a rapid growing variety. (4) Transplanting without hardening off. (5) Transplanting into a dry soil.

Control. It is evident from what has been said that the fertilizer in the seed bed should be well balanced. Care should be taken to prevent the seedlings from becoming leggy, and to see that they are properly hardened before transplanting. The Stone and its related varieties seem to be more resistant to hollow stem. On the other hand, the Dwarf Champion seems to be especially susceptible to hollow stem.

Winter Blight

Cause, unknown.

Symptoms. This disease seems to be very prevalent on forced tomatoes in the United States and Canada. Howitt and Stone,* who have recently studied this disease, describe it as follows: The leaves show distinct brown or blackened, angular, diamond-shaped spots scattered between the larger veins. When the spots are numerous and close together they appear as a distinct pattern. In a more

*Howitt, J. E., and Stone, R. E., Phytopath. 6: 161-166, 1916.

advanced stage, the primary and secondary veins also become browned. Affected stems are peppered with minute brown lesions, irregularly scattered, and apparently superficially seated. In advanced stages, however, the lesions seem to work deeply into the vascular bundles. On the fruit the disease appears as surface lesions which are variously shaped. The surface of the spot may be unbroken and smooth, or rough and scabby. In advanced stages, the superficial lesions work in deeply in the flesh of the fruit. Upon maturing, the affected areas fail to take on the normal color. Such fruit is spotted and scabby, and is worthless for market purposes. Up to the present, the exact cause of the disease and methods of control are unknown. It seems that the trouble is not caused by a pathogenic organism, but rather by some unknown chemical or physical derangement of the soil.

Blossom End Rot

Cause unknown.

Blossom end rot, also known as point end rot, may be found wherever tomatoes are grown. It is a disease of the fruit only. In some seasons fifty per cent or more of the fruit crop is ruined by it. It seems to be serious in dry weather and on light soils.

Symptoms. Infection is manifested as a water-soaked spot at the blossom end of the fruit (fig. 36, a.). The size of the spot may be that of a pinhead, or it may spread so rapidly as to involve half

of the tomato. A few days later, the water-soaked spot becomes black and leathery and ceases to make further progress. Complete rotting of the fruit may be brought about by secondary invasions.

Plants subject to frequent slight wilting produce a greater number of defective fruits. There seems no doubt but that the water supply in the soil is an important factor in limiting or increasing blossom end rot. The factors of drainage and cultivation are, therefore, important considerations. Although dry soils and drought favor the increase of the disease, the state of health of the plant itself seems equally important.

The use of fertilizers, too, seems to influence the trouble. Heavy applications of manure or of potash seem to increase the rot, as do fertilizers in the form of ammonium compounds. This is especially true on sandy loams. On the other hand, nitrate of soda or lime acts as a check. In controlling blossom end rot, the moisture of the air in the greenhouse seems also an important factor. On bright, sunny days, it is not advisable to keep the air dry. However, care should be taken not to keep the air of the house dry during the night, as this encourages numerous fungous diseases.

Sunburn

Tomatoes are often burned while they are on the vines by strong sunlight beating on the exposed fruit. This results in a scalding of certain parts, loss of

color, and a local drying which produces white spots with a dry, peppery appearance. Such fruit is unfit for the market.

Control. In houses where sunburn is prevalent it is advisable to have the house shaded and to plant varieties that have a dense foliage.

Mosaic

Cause unknown.

A lengthy discussion on mosaic has already been given on p. 102. Mosaic on tomato is a common field and greenhouse trouble, conspicuous on stalks, fruit, and leaves. On the leaves it is manifested as a mottling of yellow areas on the tissue that causes the leaves to warp and grow unevenly. In severe cases the normal leaflets are replaced by a filiform or fern-like structure, with a striking dissected form. The blossom of the diseased plant usually drops off, and the few fruits that are set are small and deformed.

Southern Wilt

Caused by *Pseudomonas solanacearum* Ew. Sm.

Symptoms. Infected plants usually wilt rapidly without losing their green color. In large leaves, the main axis is bent downward in a drooping way. With the young plants the stems and foliage also droop and shrivel. The vascular system of such plants is browned, indicating the presence of the causative organism within. Upon cutting across a freshly wilted stem, one observes that a dirty white

to brownish white slime that is not sticky oozes out. In soft and rapidly growing plants, the whole pith is often converted into a watery slime. In tomatoes and eggplants the disease seldom attacks the fruit but is confined to the vegetative parts.

Southern wilt attacks not only the tomato and eggplant, but it also causes a serious disease on potato, tobacco, peanut, nasturtium, ragweed, impatience, and verbena, in the open.

The Organism. *Pseudomonas solanacearum* is a medium-sized rod, with rounded ends and motile by means of polar flagella. Pseudo-zooglœæ are common in old cultures. No spores are formed; on agar-agar, colonies are white, then dirty white, afterwards becoming brown with age. The organism does not liquefy gelatine and produces no gas.

Control. All diseased plants should be carefully pulled out and destroyed by fire. The house should be given all the ventilation possible and water withheld for a while. Syringing of the plants should cease until the disease subsides. In watering care should be taken not to splash soil particles on the plant. All insect pests whether sucking or biting should be controlled, as these usually help to spread the disease. This trouble is likely to be prevalent in greenhouses in the Southern states.

Damping Off. See Pythium.

Late Blight

Caused by *Phytophthora infestans* (Mont.) De By.

Late blight is a disease of frequent occurrence on greenhouse tomatoes.

Symptoms. Affected plants appear as though killed by frost. The disease first shows itself as small blackened areas on the leaves, stems, and fruits. These rapidly increase in size and cause the premature death of the affected host. Fruits which may not show signs of disease will develop the trouble in transit if coming from infected houses.

The Organism. The mycelium of the fungus is hyaline, non-septate. As shown by Melhus* and others, the mycelium may be carried from year to year within the infected tubers. In fact this is but one way by which late blight is distributed. Through the stomata of the infected leaf emerge the slender conidiophores bearing the ovoid conidia. According to Melhus the conidia of *Phytophthora infestans* may germinate either directly by a germ tube or by the production of zoospores as in Pythium. The best germination occurs at the optimum temperature, which lies between 10 and 13 degrees C. (50-57 degrees F.). The conidia may be killed by exposure for six to twenty-four hours to dry atmospheric conditions such as exist in an ordinary room. Frost which kills the top of the plants will also kill the conidia of Phytophthora. Light does not hinder germination and therefore has no inhibiting effect on infection. Investigation fails to show that *Phytophthora infestans* produces sexual spores or oo-

* Melhus, I. E., U. S. Dept. of Agr. Jour. Agr. Research, 5: 59-65, 1915.

spores within the affected tissue of the leaf or tuber. However, Clinton succeeded in developing what appeared to be oospores of the fungus in pure culture on oat agar. The oogonia appear as swollen terminal heads, cut off from the main thread by a cross wall. The antheridium resembles that of *P. phaseoli*. Mature oospores have a medium thick, smooth, hyaline wall. How the oospores germinate is unknown.

Control. Late blight of tomatoes may be controlled by spraying. The best results are obtained by using 5-5-50 Bordeaux.

Buckeye Rot

Caused by *Phytophthora terrestria* Sherb.

Buckeye rot is a disease which attacks the fruit. The trouble seems to be new and has been recently described by Sherbakoff.* So far as is known, the disease has appeared only in Florida.

Symptoms. The disease, as the name indicates, appears as pale to dark greenish-brown zonate spots on the fruit. The rot is hard and somewhat dry when the fruit is green, but becomes softer as the tomato ripens. It usually begins at a point where the fruit touches the ground, which is most commonly at the blossom end, and might be mistaken for blossom end rot were it not for the characteristic zonations.

The Organism. The mycelium is at first continuous, then septate. Conidia germinate by means of

* Sherbakoff, C. D., Phytopath, 7: 119-129, 1917.

swarm spores. Chlamydospores are common, oospores frequent on cornmeal agar. Besides tomato fruit, *P. terrestria* causes a foot rot of citrus trees and a stem rot of lupines.

Control. Fruit destined for distant markets should not be packed as soon as it is brought in from the house. If possible it should be kept a few days to allow for possible rot to develop so that the affected ones may be culled out and destroyed. Spraying with Bordeaux mixture is also recommended.

Leaf Spot

Caused by *Ascochyta lycopersici* Brun.

This disease is of common occurrence but of little economic importance. It produces brown circular spots which enlarge and change to grayish brown in color.

Fruit Rot

Caused by *Phoma destructiva* Plowr.

Symptoms. On the fruit the disease is characterized by conspicuous dark spots on the side and at the stem end of both green and mature fruit. On the surface of the largest spots, numerous dark pycnidia may be seen. Besides attacking the fruit, the disease may also infect the foliage, causing dark spots which resemble those on the fruit. Affected leaves shrivel, droop, and sometimes drop off. The disease seems to be unable to attack potatoes or peppers.

The Organism. The mycelium forms a dense network of fungal threads within the host tissue. The pycnidia are subglobose, carbonaceous, smooth, slightly papillate, and with a distinct central pore. The pycnidia are scattered and few.

Leaf Spot

Caused by *Septoria lycopersici* Speg.

Symptoms. The first indications of the disease are minute water-soaked spots on the underside of the leaves. With time, these increase in size and become circular in outline with a definite margin. The spots become hard, dry, dark, and shrunken, and when numerous they coalesce into large blotches, involving the entire leaflets and leaves; the latter soon droop, dry, and cling to the stalk, until broken off by the wind or by any other jar. Within the spots are formed minute black, glistening pycnidia while the spores exude yellowish mucilaginous drops.

On the stems, the spots are similar to those on the leaves, although they are not so clearly defined, nor do they work in deep enough to form cankers. Spots may also occur on the calyx and on the fruit. The disease, however, is usually a foliage trouble. Of the more resistant varieties may be mentioned Mikado, King Humbert, Wonder of the Market, and Up to Date. Of the medium resistant varieties may be mentioned Alice Roosevelt, President Garfield, Prelude, Ponderosa, and Magnum Bonum.

The Trophy and Ficarazzi are very susceptible varieties.

The Organism. The mycelium of *Septoria lycopersici* is hyaline and septate. The pycnidia are globose; the pycnospores are hyaline, needle-shaped, many-septate, and lose their vitality when exposed to ordinary room temperature for about four days.

Control. The disease often starts on the seedlings in the seed bed. It is important, therefore, to start with a clean seed bed soil. Seedlings should be sprayed with 4-4-50 Bordeaux before being transplanted. In the house, the plants should not be worked when wet. Spraying with 4-4-50 Bordeaux is recommended.

Anthracnose

Caused by *Colletotrichum phomoides* (Sacc.) Chester.

Anthracnose is a disease to which ripe tomatoes are especially subject. The losses are often considerable both in the house and in transit.

Symptoms. The spots are at first small, but they soon enlarge. They are discolored, sunken, wrinkled, with distinct central zones, closely resembling the anthracnose of apple. In moist weather, the spots become coated with a salmon-colored layer which consists of the spores of the fungus.

The Organism. In structure, *C. phomoides* is little different from other Colletotrichums. The setæ of the fungus are very numerous, thus giving the

acervuli a black appearance. The conidiophores are short, and the conidia, oblong, hyaline and one-celled.

Control. Anthracnose depends upon a moist atmosphere for its activity. Spraying with Bordeaux is recommended.

Leaf Mold

Caused by *Cladosporium fulvum* Cke.

Leaf mold is very troublesome in the greenhouse. In some of the Southern States, however, it is found on field tomatoes also. The disease is favored by a damp, moist atmosphere.

Symptoms. The mold appears as rusty cinnamon, colored irregular, feltlike spots on the underside of the leaf (fig. 36, b), the upper part of which turns brown, then black. The affected foliage finally curls and dies.

The Organism. The conidiophores of the fungus break through the cuticle of the epidermis in a dense crowded mass. The conidia are few and are borne on the tip ends of the condiophores, which are sparingly branched and knotty. The conidia are elliptic or oblong (fig. 36, c), 1 septate.

Control. The effects of the disease are seldom disastrous if infection starts when the fruit has set and is well developed. An early infection when the plants are still young may result in the failure of the crop. Careful and thorough spraying with Bordeaux 4-4-50 before the disease appears is recommended. Spraying should be done once every

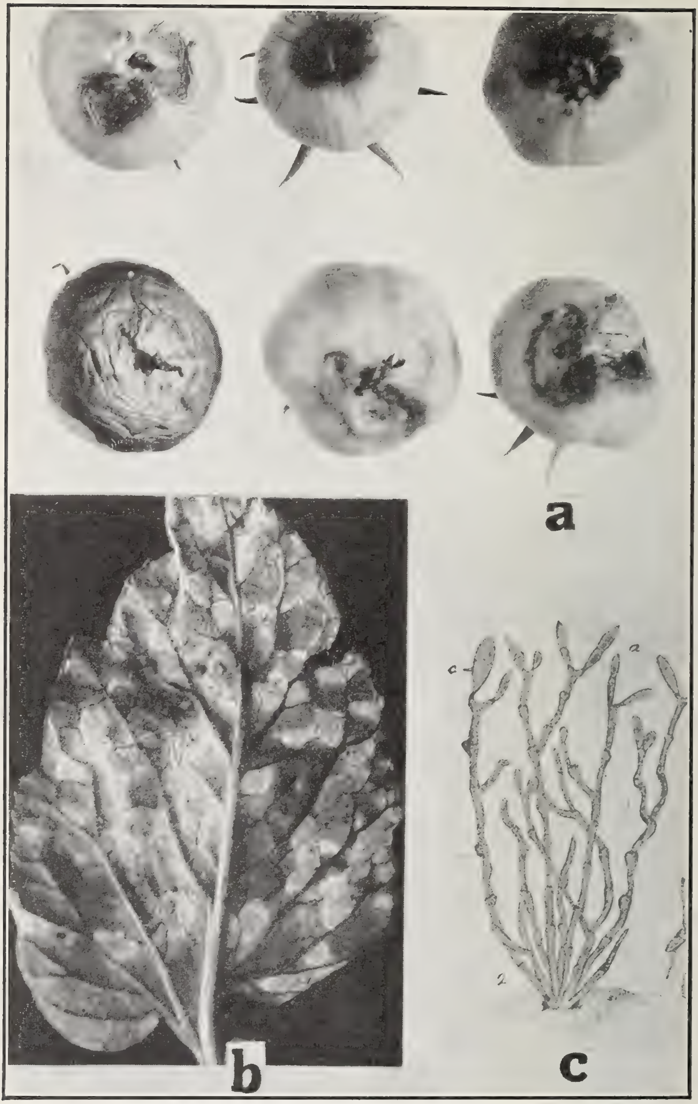

FIG 36. TOMATO DISEASES.

a. Various stages of blossom end rot, *b*. Cladosporium leaf mold, *c*. fruiting stalks and spores of *Cladosporium fulvum* (*c*. after G. Massee).

two weeks and should cease about five days before the fruit is picked. If the disease becomes well established in a house, spraying will prove of little benefit. In that case, the house should be emptied of all vegetation, the soil sterilized with steam or formaldehyde (see pp. 32-43), and wherever possible the house, too, should be fumigated with formaldehyde and potassium permanganate (see p. 164).

Black Rot

Caused by *Macrosporium solani* E. and M.

Symptoms. Black rot is a fruit, stem, and foliage trouble. The spots are black, dry, slightly wrinkled, and extend deep into the interior tissue (fig. 37, a and b.).

The Organism. The mycelium of the fungus at first varies in hue from hyaline to brown, then turns black. The conidiophores and conidia are dark, with three to six transverse and one to two longitudinal septæ (fig. 37, c.). Spraying with Bordeaux mixture is recommended.

Sleeping Sickness

Caused by *Fusarium lycopersici* Sacc.

Sleeping sickness is a tomato trouble. It is usually brought in with diseased seedlings.

Symptoms. Infected plants become pale, the leaves wilt and droop and never recover (fig. 38, a.). The droopiness of a diseased plant gives it a

sleepy appearance, hence the name of the disease. On splitting open a diseased root or stem, one finds that the interior vascular bundles are brown, due to the presence of the parasite (fig. 38, b.).

The Organism. F. lycopersici is a soil fungus which may be introduced with infected manure or seedlings. The fungus greatly resembles *F. oxysporum*. The conidia are hyaline to yellowish, falcate, acute (fig. 38, c and d.).

Control. Spraying will not control this malady since the parasite lives internally and cannot be reached by external applications. The selection of resistant varieties may offer a means of conquering this trouble. Soil sterilization with steam or formaldehyde is essential.

Black Mold

Caused by *Fumago vagans* Pers.

Black mold usually follows the attacks of the white fly. The same fungus also attacks nasturtiums grown indoors. The fungus appears as a conspicuous olive-black growth on the upper part of the leaves. The fungus in this case is not parasitic, but usually grows on the honey dew secreted by the white fly. Although the fungus is not parasitic, its presence on the leaves is undesirable since it interferes with the absorption of light by the plant. In controlling white fly, the black mold fungus will also be checked.

FIG. 37. TOMATO DISEASES.

a. Cluster of tomatoes, affected with black rot, *b.* black rot on stems, *c.* germinated spore of *Macrosporium solani* (*c.* after Schwarze).

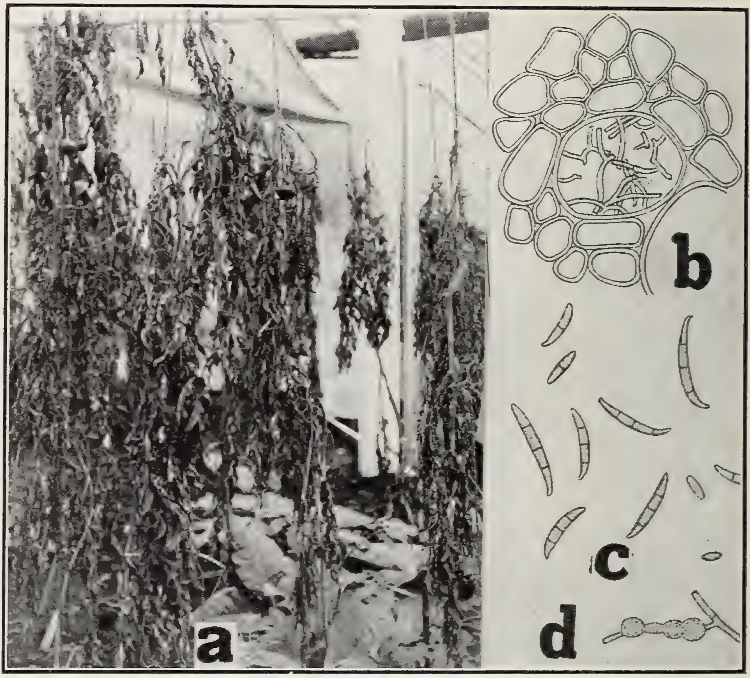

FIG. 38. TOMATO DISEASES.

a. Sleeping sickness, *b.* cross section of fibrovascular bundle of infected tomato stem showing mycelium, *c.* spores, *d.* *chalmydospores* (*b-d* after Schwarze).

Rhizoctonia Fruit Rot

Caused by *Corticium vagum* B. and C. *var. solani* Burt.

This form of rot makes its appearance at the place where the fruit touches the ground. The diseased area becomes chocolate-colored, and the epidermis slightly wrinkled. The rot extends into the interior pulp, turning it brown and dry. For a further description of the causative fungus, see p. 20.

Root Knot, see Nematode, p. 28.

Broom Rape

Caused by *Orobanche ramosa* L.

The parasite fastens itself to the tomato roots whence it derives its food. The parasite produces a base of considerable size below ground from which a cluster of branching stems and bluish-yellow flowers appear above ground. The same parasite also attacks the hemp and tobacco out of doors.

Fumigation Against White Fly

The tomato is a favorite host for the white fly.

The different conflicting results obtained by growers in the fumigation treatment may be attributed to the use of widely different varieties of plants. The variations may also be partly due to tightness or looseness in construction of the greenhouse. Inves-

tigations by Warren and Voorhees* have shown that tomato varieties such as Lester Prolific, Elongated Sparks, Earliana and Station Yellow recover from the first fumigation with almost no injury. Under the same treatment, Eclipse and Fragmore's Selected suffer lightly, while Stone, Lorillard, Beauty, Perfection, and Best of All become seriously injured. Tomato plants injured by night fumigation usually show no ill effect until about four o'clock the following day, when they wilt. If lightly injured the tops usually die. Fumigation for fifteen minutes with potassium cyanide, one ounce to each 1,000 cubic feet of glass, during the dark is satisfactory for indoor tomatoes. The house at that time should be cool and dry (fig. 39, a-c.).

* Warren, G. F., and Voorhees, J. A., New Jersey Agr. Expt. Sta. Twenty-seventh Ann. Rept.: 242-246, 1906.

FIG. 39. EFFECT OF FUMIGATION ON TOMATOES.

a. Fumigated 35 minutes in dark, *c.* fumigated 15 minutes in daylight, slight injury, *b.* fumigated 30 minutes in daylight, severe injury (after G. F. Warren).

PART IV

DISEASES OF ORNAMENTALS

CHAPTER 17

ALTERNANTHERA (*Alternanthera sp.*)

Cultural Considerations, see Coleus, p. 245.

Diseases of the Alternanthera

The Alternanthera is comparatively free from disease and it is generally considered a hardy plant.

Leaf Blight

Caused by Phyllosticta sp.

Symptoms. Alternanthera blight was first reported by Halsted* as being very serious in greenhouses of the eastern states. It is especially severe in the "cutting" benches. The trouble is characterized by a premature defoliation. The affected leaves coil up and drop off. In an early stage, the leaves become spotted merely, and it is only when the spots become numerous that the foliage drops off. The trouble is usually overlooked, because of the variegated foliage of the host. The cause of the blight is a Phyllosticta fungus, probably the same

* Halsted, B. D., New Jersey Agr. Expt. Sta., Thirteenth Ann. Rept.: 299, 1892.

as *P. amaranthi*, which attacks the pigweed, Amaranthus retroflexus.

Control. It is probable that spraying with a standard fungicide will control the trouble.

Root Rot

Caused by *Rhizoctonia solani* Kuhn.

This form of injury is commonly met with in propagating benches of Alternanthera. The young cuttings often rot off before setting roots. On well established plants, the Rhizoctonia fungus is found as strands on the sides of the branches which touch the ground. In this case there is apparently no injury. It seems that the reddish varieties of Alternanthera is covered with more Rhizoctonia strands than are the green or the variegated varieties. For a description of the causal organism and methods of control, see p. 20.

Antirrhinum (*Antirrhinum Majus*).

Cultural Considerations. Antirrhinums have become important plants, forced primarily as cut flowers. The plants require a light sandy loam compost. In filling the benches, we must avoid fresh and undecomposed manure. It is necessary also to avoid the excessive use of nitrogen. Where this is overlooked, the flowers will have a tendency to "sport" and possess too much yellow color, which is objectionable to the trade. Some growers prefer to

add to the soil a liberal application of rock phosphate and finely ground limestone. Antirrhinums thrive very poorly in wet soils. The plants should not be syringed in winter and especial care should be taken in watering on cloudy days. The plants are not injured by a night temperature of 45 degrees F., although 48 to 55 degrees suits them best. The day temperature should never run above 70 degrees F.

Diseases of the Antirrhinum

The antirrhinum, although considered a hardy plant, is subject to several diseases, most of which are of economic importance.

Rust

Caused by *Puccinia antirrhini* Diet. and Halw.

Symptoms. The Uredo stage is the one most commonly found. It is manifested as small roundish, reddish brown pustules, usually grouped circularly on the under side of the leaf or on the stem (fig. 40, a and b). The affected tissue becomes yellow. The fungus was first described by Dietel* who found the Teleuto and the Uredo stage on specimens collected in California. The fungus is very commonly found to attack snapdragons out of doors. It is also a serious trouble to growers of greenhouse plants. However, the Teleuto stage is not fre-

* Hedwigia, 36:298, 1897.

quently met with. The exact life history of this fungus is as yet imperfectly known.

Control. In the greenhouse, the disease is only prevalent on snapdragon propagated by cuttings taken from outdoor plants. In this case, the disease is brought in directly with infected cuttings. The only remedy known is to use healthy cuttings. The safest is to use plants started from seeds sown indoors.

Anthracnose

Caused by *Colletotrichum antirrhini* Stew.

Symptoms. *Anthracnose* is a common disease on greenhouse and garden snapdragons. In the greenhouse, it is more troublesome in the fall and spring. The disease attacks the stems (fig. 40, d) in all stages of development. It appears as a large spot on the stems or lateral shoots, resulting in their death (fig. 41, a and b). The spots are at first dirty white with a narrow border. Soon, however, the center turns black and under conditions of moisture, becomes covered with the acervuli of the causal organism. On the leaves (fig. 40, d) the spots are circular, slightly sunken, at first yellowish green with indefinite outline, and later becoming dirty white or greenish, definitely outlined and limited by a narrow brown border. The spots, when numerous, spread and blend together. The affected foliage shrivels, clings to the stems and dies.

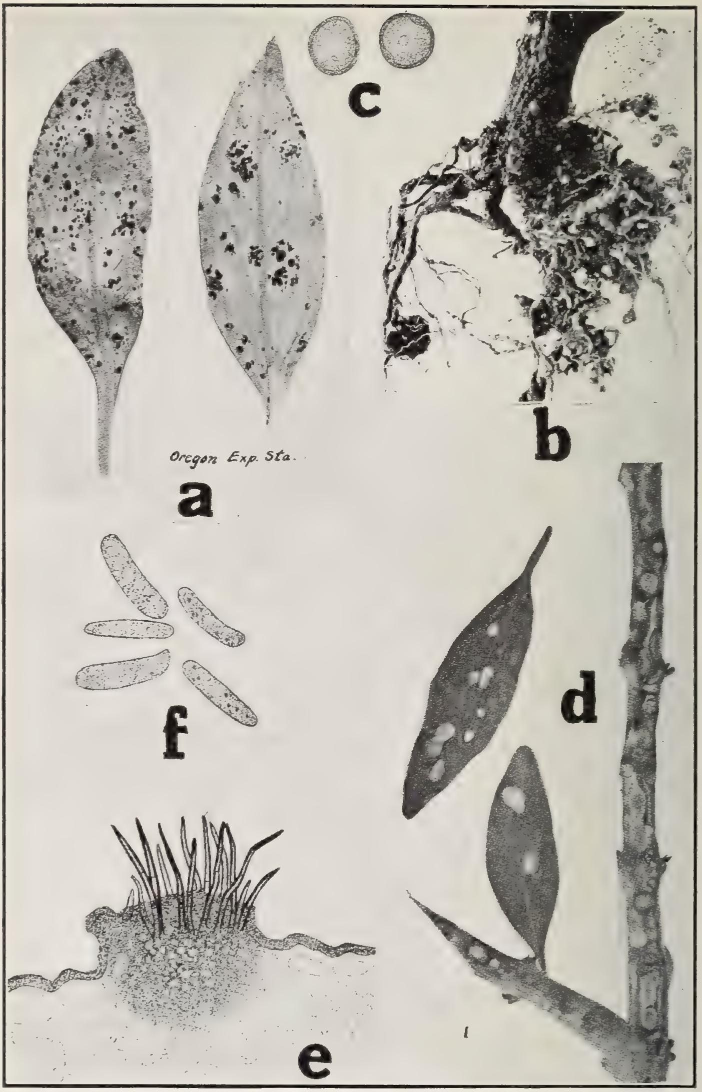

FIG. 40. ANTIRRHINUM DISEASES.

a. Rust on leaves, *b.* root knot, *c.* Uredo spores of *Puccinia antirrhini* (after Schwarze), *d.* anthracnose lesions on stems and leaves, *e.* section through an acervulus of *Colletotrichum antirrhini* *f.* spores of *C. antirrhini,* (*d-f* after Stewart, F. C.).

The Organism. The stroma is well developed; the conidia are straight to curved, with both ends rounded. The conidiophores are short, the setæ abundant, dark brown, simple, and mostly straight (fig. 40, e and f).

Control. The disease is often introduced in the greenhouse with infected cuttings. Cuttings should therefore be secured from healthy plants. This disease attacks only the snapdragon. It should therefore be an easy matter to prevent its introduction indoors. If the disease makes its appearance, spraying with Bordeaux mixture should be resorted to. All diseased material should be destroyed by fire.

Branch Blight

Caused by *Phoma poolensis* Taub.

Symptoms. The disease seems to be confined to the tender and growing shoots. It seldom affects the older and more woody stems. Affected parts wilt, and become discolored without showing any definite spotting. Later, however, numerous pycnidia appear on the dead parts.

The Organism.—Stewart* has proved by artificial inoculation that the causal organism is a parasite. The writer's investigation of this organism has confirmed the work of Stewart. In 1916 and 1917, a careful study of this disease was made, as it occurred in several greenhouse establishments in San Antonio,

* Stewart, F. C., New York (Geneva) Agr. Expt. Sta. Bul. 179: 109-110, 1900.

Texas. It was proved definitely that the organism is parasitic and that it was also apparently an undescribed species to which the name *Phoma poolensis* Taubenhaus was given. The pycnidia are minute, numerous, black, with distinct mouths (ostioles). The spores ooze out in a colorless gelatinous rope-like mass. They are small, elliptical, hyaline, and one celled.

Control. The methods of control for this disease should be the same as those used for anthracnose.

Blight

Caused by *Septoria antirrhini* Desm.

This disease is greatly dreaded by English gardeners. It was first described by Chittenden* who claims that it is very prevalent in Great Britain. Fortunately, it is not yet known to occur in the United States. The disease is characterized by a general blighting and dying of the leaves and branches.

Wilt

Caused by Verticillium sp.

This disease, although new, is prevalent all over the United States. Little is known of the disease and of the causal organism. The Verticillium, however, may be introduced with infected soil or manure, or with diseased cuttings. To prevent the

*Chittenden, J. F., Jour. Roy. Hort. Soc. 35: 216-217, 1909.

FIG. 41. ANTIRRHINUM DISEASES.

a. Healthy plant, *b.* plant killed by anthracnose (*a* and *b* after Stewart, F. C.).

disease from getting a foothold in the greenhouse, it is necessary to secure cuttings from healthy plants. Infected soils should be steam sterilized or treated with formaldehyde (see pp. 32-43). Spraying in this case will be useless since the causal organism works in the interior of the roots and stems.

Root Knot (fig. 40, b), see Nematode, p. 28.

Aspidistra (*Aspidistra Lurida*)

Cultural Considerations. This plant is very easy to grow. It is valued mostly as a foliage plant. It grows well in dark halls and in dwelling houses. The plant requires an abundance of water. It is propagated by division of rhizomes in late winter.

Diseases of Aspidistra

The Aspidistra is a very hardy plant. It is subject to the attacks of but few diseases.

Anthracnose

Caused by *Colletotrichum omnivorum* Hals.

This disease causes irregular ragged dry spots on the leaves. The spores are sickle shaped, hyaline, one celled. The setæ are black, elongate, and pointed. The disease may be kept in check by spraying with a standard fungicide. All infected material should be destroyed by fire.

Leaf Spot

Caused by *Ascochyta aspidistræ* Mas.

This disease is characterized by roundish, whitish spots on the leaves. The trouble is as yet of no economic importance. Little is known of the causal organisms. Of the other fungi recorded on aspidistra may be mentioned *Pyrenochæta bergevini* Roll.

CHAPTER 18

ASTER (*Aster sp.*)

Cultural Considerations, see Chrysanthemum, p. 235.

Diseases of the Aster

Although considered a hardy plant, asters are subject to some important diseases when grown under greenhouse conditions.

Yellows

Cause, physiological.

Symptoms. This is a very obscure disease, the cause of which is little understood. It has been investigated by Smith,* who, however, reached no definite conclusions. The roots of affected plants are apparently normal in every respect. The stems and branches, however, become pale yellow, slender and spindly, and in extreme cases stunted. The leaves too are often stunted and poorly developed. The flower bracts show no change, the calyx (sepals) has a tendency to revert to leaf-like lobes. The color of the corolla changes to a uniform light greenish yellow irrespective of the original color of

* Smith, R. E., Mass. (Hatch) Agr. Expt. Sta., Bul. 79: 3-26, 1902.

the variety. In form, the florets of the corolla become elongated, tubular, with short lobes at the ends. The stamens have a tendency to abort, the anthers are undersized, producing little or no pollen. The pistil tends to elongate, the stigma too becomes much elongated and enlarged, protruding abnormally from the corolla tube. The ovary and ovules too are elongated and enlarged (fig. 42, a and b). Affected plants produce no seeds. The same disease also attacks the Marguerite, the Calendula, and the African Marigold. The cause of the trouble is unknown. Practically all varieties of asters are equally susceptible. The source of the seed, its storage conditions, transplanting, the physical properties of the soil, are not apparently concerned in the development of this malady.

Control. It is very likely that yellows may have an origin similar to that of mosaic. In the latter case, insects are likely to carry and to spread the virus. The control of all insect pests is therefore recommended. Diseased plants should be pulled out and destroyed by fire. Spraying will be of no benefit.

Leaf Blight

Caused by *Bacillus asteracearum* Pava.

The disease is known to occur in Italy where it was described by Pavarino.* The trouble is ap-

* Pavarino, G. L., Atti. R. Accad. Lencei Rend. Cl. Sci. Fis., Mat. et Nat. 21: 544-546, 1912.

FIG. 42. ASTER DISEASES.

a. Blossoms affected with yellows, notice the one-sidedness of the petals, *b*. section of a partially diseased blossom, showing upward turn of affected florets, *c*. young plant affected with Fusarium wilt (*a-c* after Smith, R. E.).

parently confined to the foliage, the lower leaves usually becoming infected first, then dry and shrivel. Leaf blight is as yet of no importance in this country.

Wilt or Stem Rot

Caused by Fusarium sp.

Symptoms. This disease appears as soon as the plants are set out and persists throughout the growing season. It is, however, most noticeable during planting time and at blossoming. The trouble usually becomes apparent first on the lower leaves. Here the normal color disappears, turning to a dull yellowish green, followed by wilting. This seems to spread throughout the length of the stem although the disease is usually confined to one side of the plant (fig. 42, c). This gives it a very characteristic appearance, since one side of the plant has a dull-green, wilted, blighted appearance and only one half of some of the leaves and flowers are affected at first. When pulled up, the roots and stems of a diseased plant appear perfectly healthy. However, if one splits open lengthwise the stem of an infected plant, he will find that the seat of the trouble is localized in the interior of the woody or vascular tissue, the latter of which will be darkened. Infection in this case no doubt takes place in the seed, at the seedling stage. Although some plants are able to make a little headway in spite of the disease they too finally succumb. The cause of the

trouble is a Fusarium fungus, of which little is now known.

Control. Since the Fusarium fungus is a soil inhabiting organism, steam sterilization of the soil at once suggests itself. The seed should always be started on a sterilized soil, and this trouble will be entirely eliminated. Diseased plants should be pulled out and burned, and by no means allowed to find their way into the manure pile. Spraying in this case will be of no value, since the seat of the trouble is confined to the interior of the roots and stems.

Other Troubles Mistaken for Wilt. An injury inflicted by the common white grub (Lachnosterna) is often mistaken for wilt. The latter feeds on the roots, and the result is a general wilting. When the affected plant is pulled up, the grubs will be found in the act of feeding. By careful watching, they may be destroyed before serious damage results to the plants.

Another cause of apparent wilt and stunted growth may be due to the sucking of the root lice. The latter are of a bluish color, and are usually found in large number on a single plant. This pest usually is harbored in the soil, especially where asters are continually grown in the same beds. Changing the soil or sterilizing it with steam will effect a cure.

In Europe, *Fusarium incarnatum* (Desm.) Sacc. is believed to be the cause of an aster wilt there.

Damping Off

Caused by *Rhizoctonia solani* Kuhn.

Symptoms. The trouble is at first manifested as brownish spots on one side of the seedlings at the surface of the soil. The lesions increase in size until the seedlings are girdled and topple over. In time, the Rhizoctonia fungus spreads over the fallen plants and forms a mat of mycelia over them.

On older aster plants, a damping off is not produced, but instead the typical Rhizoctonia lesions appear on the stem end and on the roots. For a description of the causal organism and methods of control, see p. 20.

Root Knot

Caused by *Heterodera radicicola* Muhler.

Symptoms. The disease manifests itself when the plants are about three inches high. The younger portions of the plant produce spindly shoots with dwarfed, disfigured leaves. The color of this growth is yellowish pale to white, the flowers are small and stunted. Such plants are known to florists as "white legs." For a description of the organism and methods of control see Nematode, p. 28.

Azalea (*Azalea Indica*)

Cultural Considerations. Azaleas are very sensitive as regards water. They require plenty of moisture,

but not so much as to make the soil soggy. They demand a cool, shady house and a rather close atmosphere. The varieties forced for the Easter market should be kept in a temperature of 45 to 50 degrees F., and those forced for Christmas should be grown under a temperature of 50 to 55 degrees. Six to eight weeks before Christmas the plants are given a temperature of 60 to 65 degrees F. In providing ventilation, cold drafts should be avoided. The best time to re-pot azaleas is after blooming. Neglect in this direction may seriously interfere with next year's bloom. Azaleas are very sensitive and may be injured even by the presence of organic matter of a heat producing nature. This means that the manure in the compost must be thoroughly rotted.

Diseases of Azalea

The literature on azalea diseases is very scant. This means either that the troubles of this plant are still to be investigated or that it is a remarkably healthy one.

Leaf Spot

Caused by *Septoria Azaleæ* Vogl.

Symptoms. This disease is characterized by reddish yellow spots on the leaves. It is not of great importance economically.

The Organism. The pycnidia are immersed, globose, depressed, black. The conidia are oblong, filiform, straight or curved, 1 to 3 or more septate, and

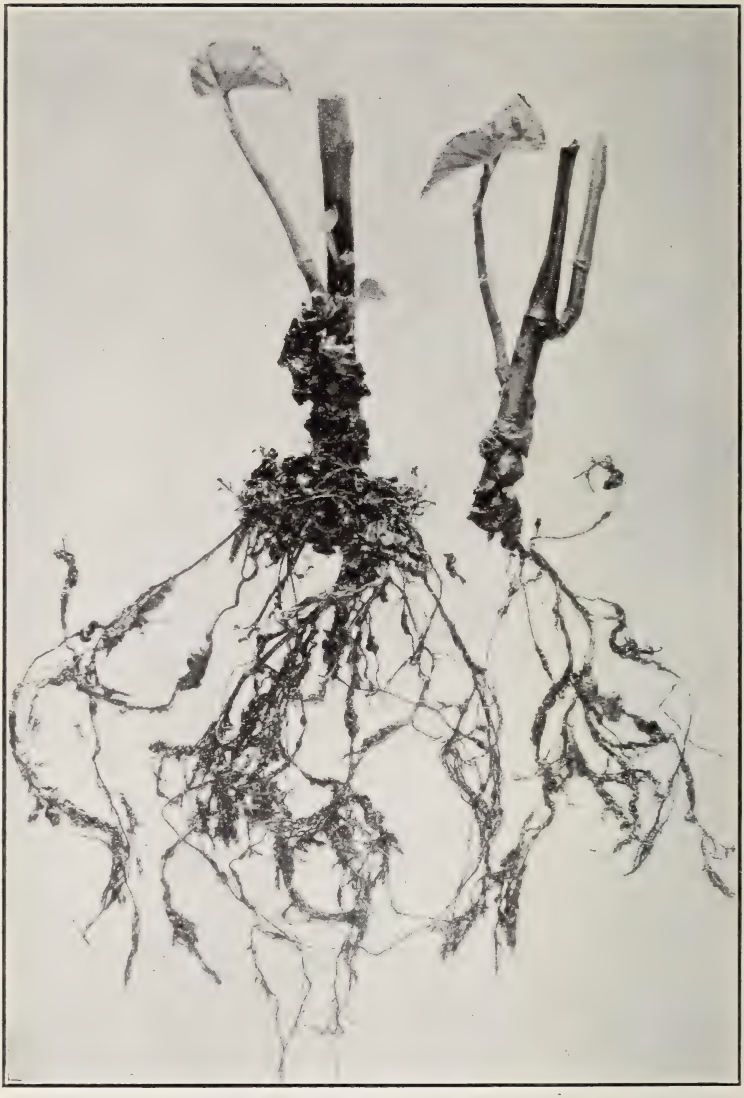

Fig. 43. Begonia Root Knot.

constricted slightly at the septum. The Conidiophores are short and cylindric.

The Begonia (*Begonia sp.*)

Cultural Considerations. Begonias have become a very popular plant commercially. The tuberous type is extensively grown under glass. Throughout the season, the plants require frequent applications of liquid cow manure. They require an abundance of light and air, but are very sensitive to draughts and to exposure to direct sunlight. The best temperature required is about 65 degrees F. In the summer, the house should be frequently syringed in order to keep it cool.

Diseases of the Begonias

Begonias, although considered hardy plants, are subject to a few important diseases.

Powdery Mildew

Caused by Oidium sp.

Stewart* records a powdery mildew attacking the stems but not the leaves of begonia. The trouble appears as a white powdery fungus growth characteristic of all similar mildews. Only the Oidium or conidial stage of the fungus is present. It is not

* Stewart, F. C., New York (Geneva) Agr. Expt. Sta. Bul. 328: 331, 1910.

likely that this disease will become troublesome in greenhouses where begonia is grown on a large scale.

Root Rot

Caused by *Rhizoctonia solani* Kuhn.

The symptoms of root rot on begonia are the same as those described for alternanthera. The fungus also causes a damping off disease on young begonia cuttings.

Root Knot (fig. 43), see Nematode, p. 28.

Caladium (*Caladium sp.*)

Cultural Considerations. Caladiums should never be allowed to become pot bound. They require a medium temperature, plenty of water, ventilation, and drainage. As the growing season is over and the plants lose their leaves, the pots should be laid on their sides and the water withheld sufficiently to prevent growth.

Diseases of the Caladium

Caladiums, it seems, are very hardy. The fungi recorded on matured parts of this plant may be mentioned:

Cercospora caladii Cke., *Macrophoma surinamensis* (B. and C.) Berl. and Vogl., *Monilia prunosa* Cke. and Mass.; *Sphærella caladii* (Schw.) Sacc., *Uromyces caladii* (Schew.) Farl.

Fig. 44. Colceolaria Leaf Blight (After Halsted).

Calceolaria (*Calceolaria arachnoidea*)

Cultural Considerations. Calceolariæ are greenhouse annuals grown for decorative purposes. It requires a soil made of equal parts of leaf mold, sand, and sand loam. The plants require frequent repotting to prevent them from becoming potbound, although the flowers are usually better when potbound. The plants require a northern exposure during the summer, plenty of ventilation, and a cool house. A temperature of 70 degrees F. may seriously injure them. Partial shading should be provided, and no water should be permitted to accumulate on the foliage.

Diseases of the Calceolaria

The Calceolaria is apparently a very resistant plant. Halsted,* however, records a leaf blight that affects it. The trouble appears as brownish patches on the leaves just about blossoming time. The patches are many sided and seem to be bound by the smaller veins of the leaf (fig. 44). The spots are water-soaked, and transparent when held against any light. The cause of this trouble seems to be a bacterial organism which, however, needs further investigation. The same is true for methods of control.

* Halsted, B. D., New Jersey Agr. Expt. Sta., 14th Ann. Rept.: 430-431, 1893.

Canna (*Canna indica*)

Cultural Considerations. The canna, although an outdoor plant, is also extensively grown in the greenhouse for propagation and for decoration. The varieties best adapted for forcing may be mentioned: Queen Charlotte, Madame Crazy, Explorateur. For flowering in the greenhouse it is best to start with dormant plants.

Fungi Recorded on the Canna

Cannas seem to be unusually free from diseases. With the exception perhaps of the rust, *Uredo cannæ*, the others here mentioned are saprophytes or semi-saprophytes attacking old and weakened plants.

Anthostomella achira Speg., *Macrosporium bulbotrichum* Cke., *Ophiobolus linosporoides* Speg., *Uredo cannæ* Wint.

Fig. 45. Type of Carnation House.

CHAPTER 19

THE CARNATION (*Dianthus caryophyllus*)

Cultural Considerations. The general trend of cultural operations in the greenhouse (fig. 45) should be toward the production of a healthy, vigorous growth. The cutting itself will, to a certain extent, predetermine the health of the plant. Cuttings should not be weak to begin with. Those which are firm, but also somewhat soft, are desirable. The best cuttings are usually made from the strong pips along the sides of the stems. As soon as the cuttings have developed roots in the propagating bed, they are usually transplanted into pots or into flats. In either case, they should not be planted too deeply in the soil. Deeply set cuttings are more subject to stem rot, especially when overwatered. As the cuttings develop they should not be permitted to become pot bound. By keeping them in a comparatively low temperature, the formation of soft succulent growth will be prevented. With many growers, carnations are grown in the field for a time. This practically insures vigorous growth as it develops a certain hardiness and resistance to disease. Where land is scarce, carnations are grown indoors in the summer. Such plants, however, are

found to be weak and susceptible to disease. In first pinching back the plants to encourage spreading, it should be done in such a way that the plants will branch some distance above the surface of the soil. In other words, the farther the stems are from the ground the more protected the plant is from disease. When the plants are permanently set for the winter, heavy watering should be avoided. Too much water compacts the soil, excludes air, and retards normal root development. As the plants become well established, and especially during the hot days of September and October, as well as in the spring, they should not be permitted to suffer from a lack of water. This is especially true in raised benches with the heating pipes directly underneath. In this case, the surface soil may appear wet, yet the soil beneath may be as dry as possible. On the other hand serious injury may occur from overwatering, especially in solid benches on cloudy days. The night temperature of the carnation house should be about fifty degrees F. At sixty degrees the plants will be stimulated to slightly earlier blooming, but the blooms will be small, and the plant subject to a more rapid exhaustion. At a night temperature of 40 degrees F. blooming will undoubtedly be retarded although the plants will be stockier and last longer. The day temperature of the house should be decided upon according to outside weather conditions. On a clear day and when sufficient ventilation is given, the temperature may run from 65 to 75 degrees F.

Diseases of the Carnation

White Tip

Cause, gas injury.

Symptoms. The trouble appears as a white or creamy coloring of the unrolled tender tips of the foliage (fig. 46, a). Occasionally, the white spots appear across the leaves a short distance below the tips. The cause of the injury is believed by Clinton* to be due to gas rather than to spray injury. The trouble may be brought about by the fumes of sulphur or tobacco used as an insecticide or fungicide. The injury affects the tip because of the tenderness of the tissue there. The Enchantress is particularly susceptible to it. The secret of its successful control lies in the care exercised during fumigation.

Sleep

Cause, gas injury.

Growers in the vicinity of large manufacturing plants are often troubled with what is called sleep of carnation. This trouble is especially common in cities where gas is used for illumination. The symptom of sleep is a closing inward of the petals (opened corolla). Once a blossom goes to sleep it never opens again. The investigations by Crocker and Knight † have shown that at least one cause of sleep in carnation is due to traces of illuminating

* Clinton, G. P., Conn. Agr. Expt. Sta., Thirty-ninth Ann. Rept.: 428-429, 1915.

† Crocker, W., and Knight, L., Bot. Gaz. 56:259-276, 1908.

gas (ethylene) in the surrounding atmosphere. This trouble has been overcome in floral establishments where lighting gas was replaced by electricity.

Malnutrition

Cause, overfeeding.

Symptoms. The trouble is usually manifested on the blossoms. It is brought about by the application of an excess of certain chemical fertilizers. Acid phosphate applied in large quantities seems to produce no injury. An excess of dried blood will produce blossoms which become soft and subject to sunburn if sprinkled during sunshiny weather. Later, such injured blossoms have their center petals bunched, and only a few others opening. Later, the buds fail to open, the foliage assumes a deep green color with abundant glossiness and a normal growth. If overfeeding is continued growth ceases. Plants thus affected may, however, recover with judicious feeding.

Overfeeding with potassium sulphate is decidedly unfavorable. The edges of the inner petals crinkle, brown spots appear, and often there is a withering of the edges of the petals, while the center ones fail to open, as though glued together. The unopened buds swell, and the pistil is commonly seen projecting one inch beyond the bud. Moreover, there is a retarded growth, the leaf tips begin to die, and the whole plant resembles a rosette.

Splitting of Blossoms

Cause, underfeeding.

Carnation growers often lose heavily from the splitting of blossoms just before they fully open. The investigations of Darner* and others seem to show that the splitting is brought about by underfeeding. The moderate application of commercial fertilizers will not cause an increase in splitting and may cause a decrease.

The splitting of the blossoms may also be noticed on the row of carnations near the glass of the side benches. The cause, it is assumed in this case, is due to the more rapid drying of the soil of the benches nearest the glass. Growers often prevent this trouble by so placing the benches as to allow a walk between them and the side walls.

Yellows

Cause unknown.

Symptoms. True yellows as described by Lamkey † appears as a yellowing (mottled chlorosis) on the leaves. The mottling is brought about by the presence of indefinite irregular blotches or flecks which meet and form yellow streaks. The mottling is more common on the younger leaves, and the streaks on the older ones. The yellow areas may become red or pink. The spots are never water-

*Darner, H. B., et al., Illinois Agr. Sta. Bul. 176: 378-379, 1914.
† Lamkey, M. R., The American Flor. 58: 508-510, 1917.

soaked and possess no watery margin. They are always sunken, and possess no definite center. The cause of the trouble does not seem to be associated with any parasitic organism, but is probably due to improper cultural conditions, the exact nature of which is unknown.

Control. The control for yellows, as recommended by Peltier* is as follows: Every check which tends to lower the vitality of the plant should be avoided. Weaker plants are more subject to yellows than stronger ones. Cuttings should never be taken from plants showing yellows. They should be made, too, from plants in bloom rather than from stock plants. They should be rooted early and should not be permitted to remain too long in the sand after rooting. The later the cuttings are made, the longer they take to root, and the more susceptible they are to yellows. Young plants should not be allowed to become pot bound.

Cohesion of Petals

Cause unknown.

Carnation growers are often troubled by what is generally termed cohesion of petals. The latter are well out of the calyx, but are stuck together. Often they are grown together to such an extent that it is impossible to separate them without tearing the tissue. The trouble was first described by Arthur,† but the exact cause of it is as yet unknown.

* Peltier, G. L., The American Flor. 46: 725-726, 1906
† Arthur, J. C., Proc. Amer. Carnation Soc., 1896.

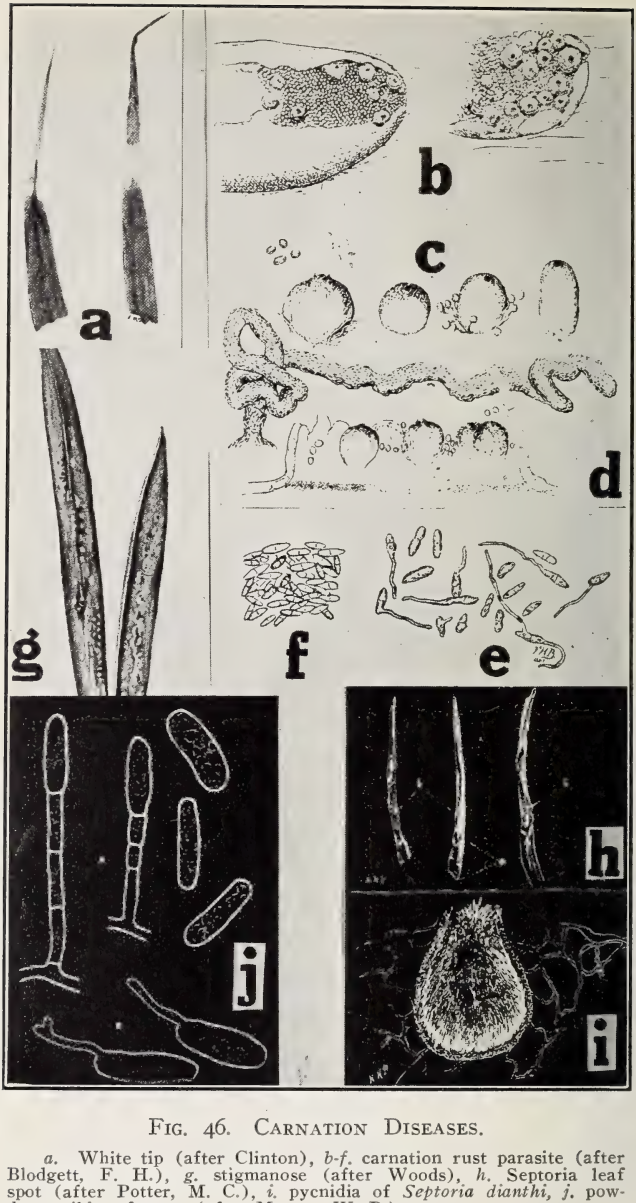

FIG. 46. CARNATION DISEASES.

a. White tip (after Clinton), *b-f.* carnation rust parasite (after Blodgett, F. H.), *g.* stigmanose (after Woods), *h.* Septoria leaf spot (after Potter, M. C.), *i.* pycnidia of *Septoria dianthi*, *j.* powdery mildew fungus (after Mercer, W. B.).

Stigmonose

Caused by insect sting.

Symptoms. The best symptoms of this disease are manifested on the younger, but full-sized leaves nearest the upper end of the stem. A casual glance at such leaves reveals little to the untrained eye. However, by holding them near the sunlight, small dots may be seen scattered. These dots have a faint yellowish color. Later the surface tissue dries and the dots assume a whitish, reddish, or purplish color, while the spots enlarge and become sunken (fig. 46, g.). Such spots are seldom dark colored in the center nor are they made up of concentric rings. With the increase of the spots, the leaves wither, but cling to the stems. The general effect of stigmonose is a premature yellowing and stunting of the plant. The vigor of the plant at the time of the appearance of the disease largely determines the severity of the injury. Strong plants will become spotted, but will in no other way greatly suffer from it. Weak plants of the same variety will become stunted, and in many cases seldom outgrow the disease.

The cause of the disease was first attributed by Arthur and Bolley* to a bacterial organism *Bacterium dianthi* Arthur and Bolley. However, the investigations of Woods † show that stigmonose is

* Arthur, J. C., and Bolley, H. L., Indiana Agr. Expt. Sta. Bul. 59: 17-38, 1896.

† Woods, A. F., U. S. Dept. of Agr. Div. of Veg. Pathl. and Phys, Bul. 19: 7-30, 1900.

caused by the stings of aphides, thrips, and red spiders. The irritant injected by these pests causes the cells to react and finally to collapse, resulting in the specking previously mentioned.

Control. The carnation is a plant which is naturally adapted to a dry atmosphere. Under such conditions in the greenhouse aphides, thrips and red spiders are at their maximum activity. To keep these pests in check fumigation with tobacco extracts or hydrocyanic acid gas is resorted to. The use of the latter, however, cannot be recommended for all carnation varieties.

Rust

Caused by *Uromyces caryophyllinus* (Schrank) Wint.

Symptoms. The rust is readily recognized by elevated blisters or sori filled with brown spores. The sori are first covered by the epidermis of the host, but when they ripen the latter bursts open, liberating the mature spores. This disease is more prevalent in overheated and overwatered houses. Infection once established will usually destroy a large per cent of the plants and seriously cripple many others. The disease may be found on all parts of the plant except the roots. Carnation rust seems to be more prevalent in the states lying east of the Alleghenies. Few greenhouses seem to be entirely free from the rust.

The Organism. The fungus has two spore stages,

the uredospores and teliospores, both of which forms greatly resemble each other. The Æcia are found on Euphorbia gerardiana in Europe and is recognized as *Æcidium euphorbi erardianæ* Fisch. The rust fungus attacks not only the carnation, but several other species of the pink family.

Control. Some florists advocate the use of an aqueous solution of common table salt. This is to be applied as a fine spray. Investigations by F. C. Stewart* have shown that salt solutions can neither prevent rust infection nor stimulate growth. Neither is it helpful to apply salt to the soil. Carnations are propagated chiefly by cuttings. The latter often carry the disease. It is, therefore, imperative that cuttings be taken from healthy plants. Maintaining the proper temperature and ventilation, as well as exercising care and judgment in watering, will help to keep this rust in check. Subirrigation is preferred to overhead irrigation to keep the plants dry. Progressive growers use an inverted V-shaped wire netting (one-inch mesh) placed between the rows. The wire is cut into strips of fifteen inches width. These are bent and inverted, about six inches high and eight inches wide, and placed between the rows of plants. This support to the foliage prevents it from touching the wet ground and admits at the same time perfect ventilation. It also makes it possible to water the soil without wetting the plants. The trouble may, of course, be avoided to

* Stewart, F. C., New York (Geneva) Agr. Expt. Sta., 16th Ann. Rept.: 423-425, 1895.

a great degree by growing resistant varieties. The Scott and the Jubilee are two varieties very susceptible to rust. On the other hand, the Enchantress and the Lawson are highly resistant.

A Parasite of Carnation Rust. Most parasites have others to live on them. The carnation rust seems to be no exception. The fungus *Darluca filum* (Bin.) Cast. was found by Blodgett* to parasitize the carnation rust fungus. The presence of the Darluca is manifested by a dwarfed and weak development of the rust pustules. The pycnidia of Darluca (fig. 46, b and c) are found scattered on the rust pustules and are flask shaped, the spores are two-celled (fig. 46, e and f), colorless, and when ripe escape in masses of long tendrils, held together by a gelatinous substance in the outer cell wall of the spore (fig. 46, d.). The latter readily germinate in water. *Darluca filum* also attacks the asparagus rust fungus. It is possible to grow Darluca in pure culture and to inoculate its spores on the carnation rust fungus. In nature, however, it has not proved abundant enough to keep the rust in check.

Septoria Leaf Spot

Caused by *Septoria dianthi* Desm.

Symptoms. Leaf spot is characterized by light brown patches on the leaves and stems. On the latter, the spots are usually found midway between

* Blodgett, F. H., New York (Geneva) Agr. Expt. Sta., Bul. 175: 1-13, 1900.

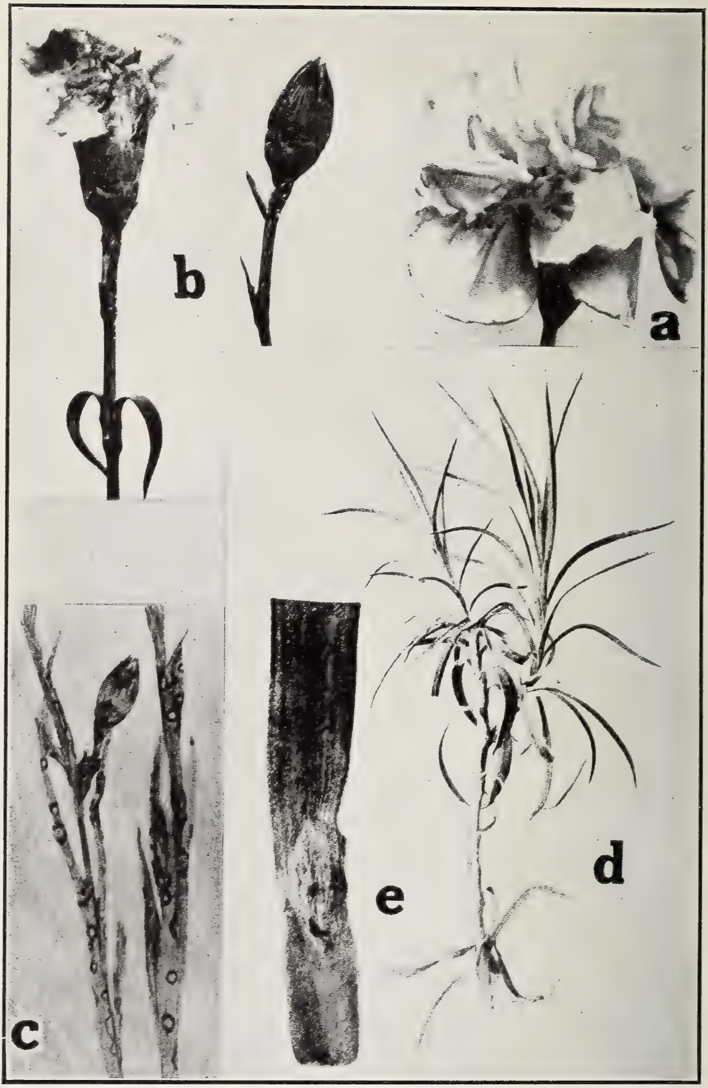

FIG 47. CARNATION DISEASES.

a. Healthy blossoms, *b.* blossoms affected with Sporotrichum rot (after Stewart, F. S. and Hodgkins), *c.* Heterosporium spot (after Smith, R. E.), *e-d.* Alternaria spot (after Stevens and Hall).

the joints. On the leaves, infection seems to be more localized on the lower than on the upper half, and it is particularly frequent on the broad sheathing base of the leaf (fig. 46, h.). Affected foliage is often bent downwards. A leaf with numerous spots may be bent at various places, downward as well as sideways. The spots are usually indefinite in size and outline. Within the dead area may be found numerous minute fruiting bodies (pycnidia).

Powdery Mildew

Caused by Oidium sp.

Mention of this disease is made by Mercer,* who found it on greenhouse carnations in England. It has not yet proved of economic importance in the United States. This trouble appears as white, powdery patches on the leaves, calyx, and corolla. The English varieties most susceptible are "Lady Arlington," "Bridesmaid," and especially "British Triumph." So far only the conidial or Oidium (fig. 46, g) stage of the fungus is in evidence. The ascus or winter spore stage may probably appear on other hosts. The trouble may be kept in check by dusting with flowers of sulphur or by spraying with potassium sulphide as recommended for the rose mildew (see p. 323).

*Mercer, W. B., Jour. Roy. Hort. Soc. 41: 227-229, 1915.

Bud Rot

Caused by *Sporothrichum poæ* Pk.

Symptoms. This disease seems to be confined to the floral buds only. Ordinarily the affected buds fail to expand or only open part way (fig. 47, a and b.). A close examination will show that the interior of the affected bud is browned and moldy. The rotted tissue may be found in the center of the bloom or on the petals. The stamens, styles, and pistils are also frequently affected. Where young buds are diseased the calyx, too, will be involved, otherwise it is usually sound, although the other parts of the flower may be decayed.

The Organism. The hyphæ are creeping, varying in thickness, hyaline, and septate. The conidia are of two kinds: Microconidia—one-celled, globose or broadly ovate; Macroconidia—abundant, one, rarely two, septate and several times larger than the microconidia (fig. 48, g to i.). Stewart* claims that *Sporotrichum poæ* Peck found on diseased tops of June grass and *S. anthophilum*, which causes the bud rot of carnations are the same. The fungus is spread about in the greenhouse by a mite (*Pediculopsis graminum* Reut.).

Control. According to Heald † and others the most susceptible varieties to bud rot may be mentioned—the Lawson, Enchantress, Queen Louise,

* Stewart, F. C., and Hodgkiss, H. E., New York (Geneva) Agr. Expt. Sta. Tech. Bul. 7: 84-119, 1908.

† Heald, F. D., Nebraska Agr. Expt. Sta., Bul. 103: 3-31, 1908.

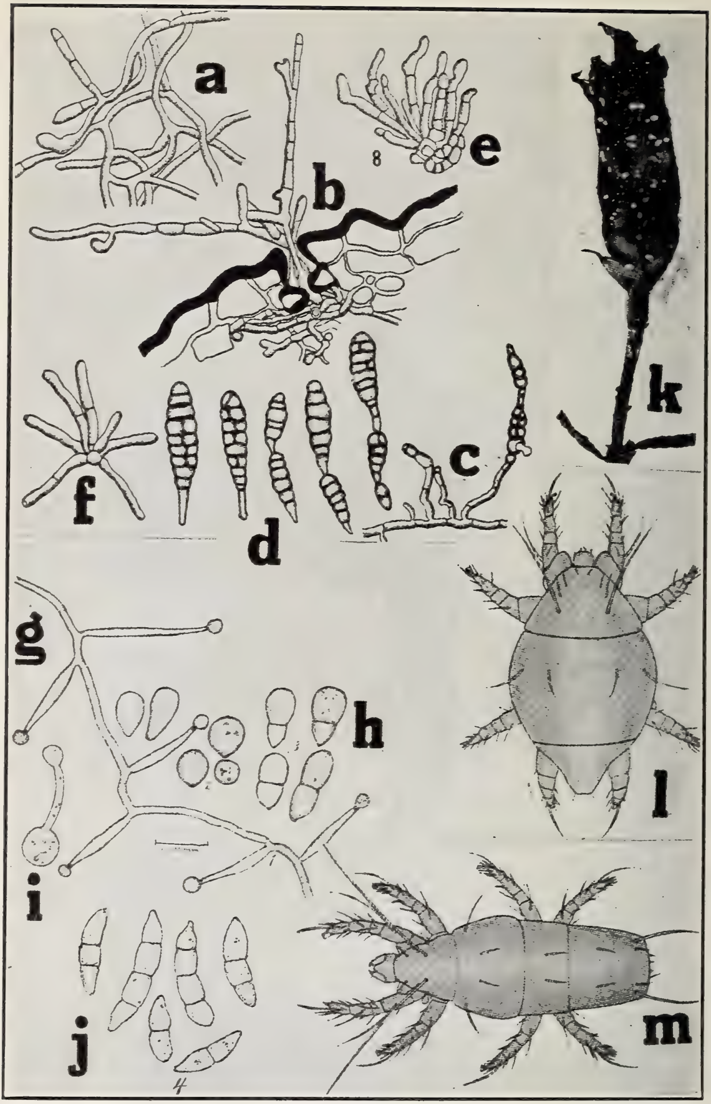

Fig. 48. Carnation Diseases.

a. Mycelium of *Alternaria dianthi* showing branching and septation, *b*. mycelium below stroma and hypheæ emerging through the stroma, *c*. catenulate spores as borne upon hypheæ, *d*. spores, *e*. an old cluster of conidiophores, *f*. a young cluster of conidiophores (after Stevens and Hall), *g*. hypheæ of Sporotrichum poae with immature spores on short tapering branches, *h*. typical spores of S. poae, *i*. germinating spore, *j*. Fusarium like spores of S poae, *k*. carnation blossom rotted, showing eggs of mites, *l*. female mite, *m*. male mite (after Stewart, F. C, and Hodgkiss, H. E.).

and Bradt. These, therefore, should be handled with more care. All diseased buds should be picked off and destroyed by fire. The temperature and moisture in the air should be kept as low as possible. The fact that the mite which is associated with bud rot (fig. 48, k to m) is also found on June grass would suggest the necessity of avoiding sod where this grass is common, in the making of the compost. This, however, may not be important when the soil is steam sterilized.

Leaf Mold

Caused by *Heterosporium echinulatum* Berk.

Symptoms. The disease becomes apparent as roundish spots, varying from a sixteenth to a sixth of an inch in diameter, and is found mostly on the tip of the leaves. In severe cases the entire leaf and even the major tops of the plant become spotted (fig. 47, c.). According to Halsted* the color of the spots is pale ashy and covered with a fine, dense growth of the causal fungus, giving it the moldy appearance. Frequently the color changes to a gray shade, sometimes approaching dark brown.

Alternaria Leaf Spot

Caused by *Alternaria dianthi* Stevens and Hall.

Symptoms. This trouble manifests itself as ashen

* Halsted, B. D., New Jersey Agr. Expt. Sta., Fourteenth Ann. Rept.: 386, 1893.

white spots, the centers of which are occupied by a scanty or profuse black fungus growth, which is made up of the spores of the fungus (fig. 47, d and e.). The spots are dry, rather shrunken, circular or somewhat elongated. If the node of the stem is attacked, the disease spreads sufficiently to involve the adjoining foliage as well. The stem itself becomes somewhat girdled and in time is also killed. Usually, however, the spots are confined to the foliage.

The Organism. The mycelium is dark brown. (fig. 48, a.). The conidiophores arise from a stroma, usually from one to twenty-five in number, and each one to four septate (fig. 48, b, e and f.). The conidia are borne in chains (fig. 48, d.), and in structure are very typical of other Alternarias (fig. 48, d.). The fungus grows well on various culture media. On media poor in sugars, the mycelium and spores are lighter in color and smaller in size and diameter.

Control. All infected material should be collected and destroyed by fire. Spraying with a standard fungicide is also recommended. From the observations of Stevens and Hall,* the variety Mrs. Thomas W. Lawson appears to be the most susceptible to this disease. As far as possible, this variety should be avoided.

Anthracnose

Caused by Volutella *sp.*

Symptoms. The disease usually attacks the base

* Stevens, F. L., and Hall, J. G., Bot. Gaz. 47: 409-413, 1909.

of the lower leaves as well as the stems which are closest to the ground. The trouble is seldom found on the upper leaves, although they may present a sickly pale appearance. Anthracnose is a serious disease of young cuttings. Not infrequently the grower loses 50 per cent of his cuttings from this disease. These damp off very quickly under a great variety of conditions.

Damping Off

Caused by *Volutella leucotricha* Atkinson.

This disease seems to be confined mainly to carnation cuttings. The symptoms are not different from those of the damping off caused by other fungi. In this case, the causal organism, *Volutella leucotricha*, first described by Atkinson,* is distinct from *V. dianthi* Hals. The mycelium of the former has a tendency to swell at the hyphal cells, producing a strong constriction at the septa. The conidia of *Volutella leucotricha* are considerably smaller than those of *V. dianthi* and the setæ are different in form and in color. In *V. leucothrica* they taper but little towards the free end, are blunt at the tip and many times septate, with the stroma light colored, while it is black in *V. dianthi*. The methods of control are the same as those for other damping off diseases (see p. 17).

* Atkinson, G. F., New York (Cornell) Agr. Expt. Sta. Bul. 94: 260-264, 1895.

Fusarium Leaf Spot

Caused by Fusarium sp.

Symptoms. This form of leaf spot usually follows the injury caused by the rust fungus (*Uromyces caryophyllinus*). The variety Emily Pierson is especially subject to the attacks of this peculiar leaf spot. The spots are large, often occupying the entire width of the leaf. The diseased tissue becomes covered with a pinkish mold in the center of which are found minute spore clusters of the Fusarium fungus. Little is known of the causal organism. In controlling rust, the leaf spot will also be kept in check.

'Branch Rot," Dry Stem Rot, or Die Back

Caused by Fusarium sp.

Symptoms. This troublesome carnation disease was first described by Sturgis.* Attacked stems and branches wilt rapidly and the color of the leaves turns to a yellowish green. Dead stems remain firm, although wilted and shriveled. The bark likewise remains firm. The causal fungus seems to gain entrance through cuts or wounds. With cuttings the trouble may start at the base, causing them to dry up and to lose their normal color. The conditions which favor the disease are excessive rains in the summer when the plants grow out of doors. This favors a large, bushy, soft growth, with a

*Sturgis, W. C., Conn. Agr. Expt. Sta., Rept. 21: 175-181, 1898.

consequently profuse topping, which opens the way to the disease.

Control. Peltier* recommends the use of medium sized sturdy plants in preference to large, bushy ones. As much as possible, overcrowding should be avoided. During the first three months after the plants have been brought in, the temperature should be kept as low as the plant will tolerate. The syringing should never be given in the evening nor in the cloudy weather. It should be given on clear days in the morning so that the plants will be dry by the evening. In topping a plant, care should be taken to make clean cuts and to avoid leaving stubs. In gathering flowers, break them off at a node. Finally all diseased material should be pulled out and destroyed by fire.

Root Rot

Caused by *Rhizoctonia solani* Kuhn.

Symptoms. The disease is at first manifested by a yellowing of the affected plant or branch. A few days later actual wilting takes place. This is true only in sunny weather. During cloudy weather, the plant remains turgescent even though the stem may be badly rotted. The trouble is confined to the stem end or to the roots of the plants. Deep brown lesions usually precede the rot and indicate the places where infection started. High temperatures and deep planting favor the disease. Of the

*Peltier, G. L., The Amer. Flor. 56: 725-726, 1916.

older varieties, the following are reported as being especially susceptible to stem rot: Crimson King, Scott, Jubilee, La Purité, De Graws, Servan, Silver Spray, Flora Hill, McGowan, Portias, Boston Market, Craig, Lawson, Winson, and Lady Bountiful. The newer varieties do not seem to possess any more resistance than the older ones. For a description of the causal organism and methods of control, see p. 20.

Root Knot

Caused by *Heterodera radicicola* (Greef) Muller.

Symptoms. Root knot is characterized by swellings of the roots. Affected plants are decidedly dwarfed, yellowish, and sickly looking. The roots of diseased plants are extensively knotted, and lumpy. For a description of the causal organism and of methods of control, see p. 28.

Fig. 49. Type of Chrysanthemum House.

CHAPTER 20

THE CHRYSANTHEMUM (*Chrysanthemum sp.*)

Cultural Considerations. Chrysanthemum cuttings should be thick, firm, have several joints, and be about three inches in length. If the cuttings within three weeks fail to make a good root system, they should be discarded as weak stock. A house temperature of 50 degrees F. and a bottom heat of 60 degrees is best suited for the cuttings. It is very unwise to allow the cuttings to remain in the propagating bed as soon as they start to grow. In transplanting for the first time the soil should not be too rich. A good loam with very little rotted manure is all that is required by the newly rooted cuttings. As the plants are finally set in benches in the greenhouse (fig. 49) they need a rich soil, as they are heavy feeders. The benches need not be over five inches, the depth of the soil not over four inches. As the plants are first set out in the benches, it is advisable to water only around each plant. As they become well established the entire bed may be watered with safety. It should be borne in mind that the soil must be kept moist very uniformly. Sudden drying of the soil checks growth, and too much will cause the leaves to become yellow and sickly. On bright days, syringing the foliage is

very helpful. This, however, should be done in the early part of the day, so that the foliage will be dry at night. Chrysanthemums are heavy feeders, and this should not be lost sight of.

Diseases of Chrysanthemums

Chrysanthemums are subject to several important diseases. These often become so troublesome as to seriously interfere with the profitable culture of the plant.

Crown Gall

Caused by *Pseudomonas tumefaciens* Ew. Sm.

This disease causes swellings on the crown and the roots of the plant. The trouble is seldom of any economic importance under greenhouse conditions. The causal organism attacks not only chrysanthemum, but also the daisy, geranium, sugar beet, poplar, willow, peach, etc.

Black Speck

Caused by *Pilobolus crystallinus* (Wigg.) Tode.

The speck is often found on the leaves. Some growers believe this specking due to the accumulation of smoke settled on the leaves after fumigation. Others believe that it is due to a condensation of ammonia arising from fresh manure. As stated for a similar case on roses (see p. 321), the specking is due to the discharge of sporangia of

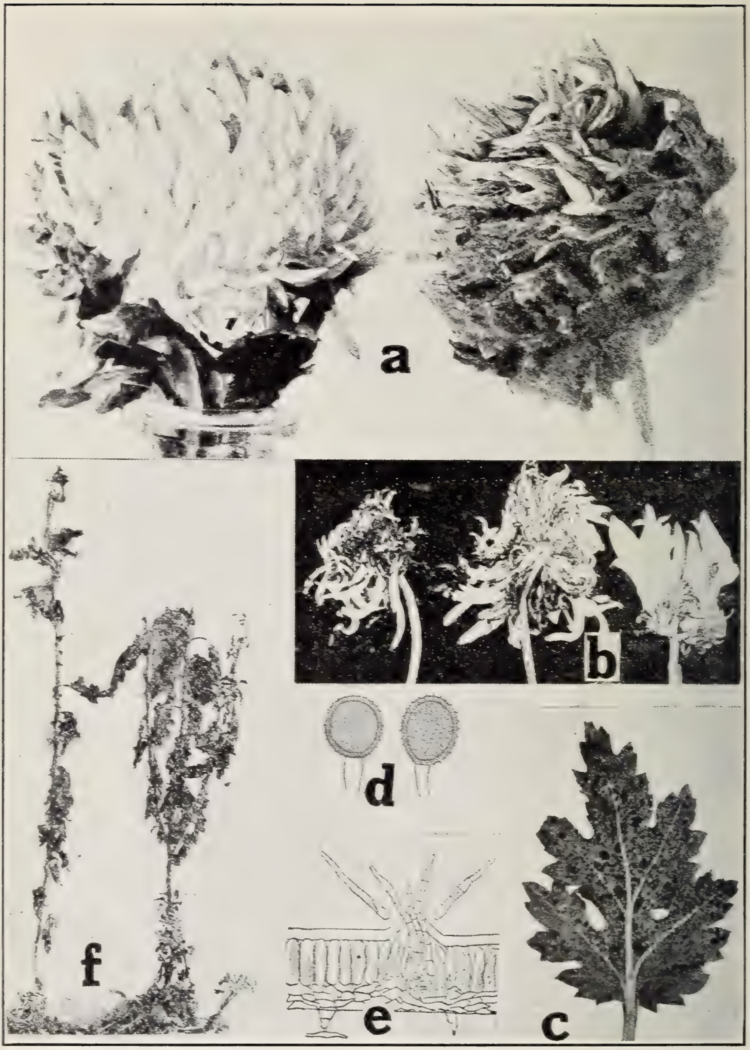

FIG. 50. CHRYSANTHEMUM DISEASES.

a. Botrytis blossom rot. healthy and diseased (after Spaulding), *b.* ray blight (after Stevens, F. L.), *c.* chrysanthemum rust (after Smith, R. E.), *d.* Uredospores of *Puccinia chrysanthemi*, *e.* Cylindrosporium fungus, *f.* Cylindrosporium blight (*e* and *f* after Halsted).

Pilobolus crystallinus. The spore-bearing stalks of this fungus are possessed with a mechanism which throws off the ripe spores considerable distances. Being covered with a sticky substance, these spore masses readily adhere to anything standing in the way. The specking may be expected wherever manure is used as a mulch. According to Craig* the trouble may be promptly stopped by a light application of air-slaked lime.

Rust

Caused by *Puccinia chrysanthemi* Rozc.

Symptoms. Rust may be readily distinguished from all other diseases of the chrysanthemums. It appears as tiny, rusty blisters the size of a pinhead. When several appear together the blister assumes a larger size (fig. 50, c.). At first, the blister is covered by the epidermis of the leaf. With age, however, the epidermis bursts and breaks away, exposing a brown powder which is made up of millions of spores of the rust fungus. On badly infected plants, the leaves may be all covered with the rust sori which nearly always appear on the underside of the leaf. It was previously believed that the rust of chrysanthemum was the same which attacks common weeds belonging to the same compositæ family as the chrysanthemum. However, the investigations of Arthur † have definitely shown that

*Craig, J., Canada Expt. Farms Repts., 1897: 91-133, 1898.
† Arthur, J. C., Indiana Agr. Expt. Sta. Bul. 85: 143-150, 1900.

the chrysanthemum rust attacks this plant and no other host. Uredospores from dandelions, burdock, ox-eye daisy, when sown on the chrysanthemum failed to produce the rust. On the other hand, uredospores taken from the chrysanthemum and sown on chrysanthemum hosts reproduce the disease. The disease no doubt is brought in with infected plants, or cuttings made from a rusted plant.

The Organism. It is very strange that the uredospore stage (fig. 50, d) is the only stage of the chrysanthemum rust that is found in the United States. This makes the fungus short lived unless it is continually transmitted from living chrysanthemum leaves to others. The uredospores are spherical to pyriform, possessing a spiny membrane and three germ pores. The teleutospores were mentioned and figured by Massee * and by Roze.† However, without making cultures it is doubtful whether these claims can be accepted as final.

Control. It is claimed that the variety Queen is very susceptible to rust. It is also believed that pot-grown plants are less resistant to rust than are plants growing in benches. Hand picking, selecting of clean, strong stock, and inside culture are recommended to keep the rust in check. The chrysanthemum rust, although serious, need not be feared by the careful grower who selects his stock and who is careful about the watering and the ventilation of the house.

*Massee, G., Gard. Chron. 24: 269, 1898.
† Roze. Bul. Soc. Myc. de France 17: 88, 1900.

Ligule Rot

Caused by *Sclerotinia fuckeliana* (De By) Fckl.

This rot in which the ligules become involved is often mistaken for a heart rot, and a destruction of the receptacle. The latter disease is brought about by nutritional disturbances. Ligule rot is caused by the fungus, *Botrytis cinera*, the fruiting summer stage of *Sclerotinia fuckeliana.*

Control. For ligule rot Crepin* recommends that the flower buds be sprinkled with a solution made up of two grams of chemically pure nitric acid to a liter of water.

Blossom Rot

Caused by *Sclerotinia fuckeliana* (De By) Fckl.

Symptoms. This disease is usually confined to the blossoms only. The trouble first appears as minute discolored watery spots on the petals, giving the latter the appearance of having been pricked with a needle. The white-flowered varieties show the spotting more distinctly than the colored ones. The spots rapidly enlarge and involve the entire corolla. Diseased petals wilt, and are soon covered by a grayish, velvety growth (fig. 50, a), consisting of the summer fruit (Botrytis). After the first few flowers become affected, the trouble spreads

* Crepin, H., Jour. Soc. Nat. Hort. France 11: 52-59, 1910.

rapidly and causes great damage. According to Spaulding* no one variety or color of chrysanthemum showed any difference in resistance.

Besides chrysanthemums the disease also attacks poinsettias (Euphorbia pulcherina). In this case the projecting angles on either side of the leaf become affected. It seems that with poinsettias, infection is localized in the broad green leaves which grow along the stems below the red zones. At the place of infection there is an exudation of small white drops of the hardened juice along the larger veins. These hardened drops of juice on the dead spots are very characteristic of the disease on poinsettias. Infected leaves drop off prematurely, thus marring the appearance of the plant. About two days after infection, the characteristic fruiting of the fungus makes its appearance.

Phyllosticta Leaf Spot

Caused by *Phyllosticta chrysanthemi* E. and D.

Symptoms. The spots are orbicular, purplish brown with a distinct border. The trouble is mostly confined to the leaves.

Little is known as yet of the causal organism. It is probable that spraying with a standard fungicide will control the trouble.

* Spaulding, P., Missouri Botanical Garden, Twenty-first Ann. Rept.: 185-188, 1910.

Ray Blight

Caused by *Ascochyta chrysanthemi* Stevens.

Symptoms. This disease attacks the buds or the opened blossoms. The affected blossom becomes brownish, straw colored, and withers. The discoloration nearly always begins at the base and works up to the tip of the blossom. Affected buds fail to open altogether. On opened flowers, the disease attacks on one side so that the rays in that direction will become destroyed (fig. 50, b.). The receptacle and the peduncle of diseased blossoms turn black and become shriveled. Portions of the stem may also be attacked, turn black and girdled.

The Organism. Ascochyta chrysanthemi was first described by Stevens.* The pycnidia are few, occur singly or scattered about, and open by means of a short central ostiole. The spores are oblong, straight or irregular, hyaline, one septate, the ends obtuse or acute.

Control. All diseased material should be destroyed by fire. Careful and frequent spraying will control the disease.

Septoria Leaf Spot

Caused by *Septoria chrysanthemi* Cav., and *S. chrysanthemella* (Cav.) Sacc.

Symptoms. This disease usually appears as small

*Stevens, F. L., Bot. Gaz. 44: 241-258, 1907.

dark brown spots which increase in size until they meet. Affected foliage drop off prematurely. Diseased plants become weakened and produce small flowers. The disease is often introduced in the greenhouse with infected cuttings. The pycnidia of the fungus are minute, while the conidia are obscurely septate.

Control. Cuttings should be secured from healthy plants. All diseased leaves and trash should be destroyed by fire. Spraying with a standard fungicide is also recommended.

Blight

Caused by *Cylindrosporium chrysanthemi* E. & D.

Symptoms. This disease seems to work quickly and affected plants are short lived. The trouble appears on the leaves as dark blotches about one-half of an inch to three-quarters of an inch in diameter. The spore heaps are formed on the dead tissue where the spots occur. The area beyond the spot turns yellow, and soon the leaves shrivel, droop, and cling to the stems (fig. 50, f.).

The Organism. The acervuli of this fungus are imbedded, the conidia are somewhat thick but taper to the end; they are several septate and straight (fig. 50, e.).

Control. Infected material should be destroyed by fire. Spraying with a standard fungicide will protect the healthy plants.

Powdery Mildew

Caused by *Oidium chrysanthemi* Robh.

This is a very common trouble of indoor chrysanthemums. Affected leaves become covered with a powdery white growth. It seems that the Oidium or summer stage is the only one that occurs on affected plants. The winter or ascus stage has not yet been recorded. The trouble may be controlled in the same way as the rose mildew (see p. 323). Some growers prefer to use sulphur by mixing it with an oil and applying it to the steam pipes as a paint.

Cineraria (*Cineraria cruenta*)

Cultural Considerations. The culture of this plant is very simple. However, it should be kept in mind that it is injured by hot dry air and sensitive to slight frost. The plant should be syringed practically every day, winter or summer. It also requires a cool shaded part in the house.

Fungi Recorded on the Cineraria

The Cineraria, it seems, is very hardy. The following fungi have been found on weakened or dead parts of the plant: *Æcidium cinerariæ* Rosti, *Ascochyta fibricola* Sacc., *Coleosporium sonchi* (Pers.) Lev., *Leptosphæria vagabunda* Sacc., *Puccinia eriophore* Thum.

Clematis

Cultural Considerations same as Cyclamen, p. 248.

Diseases of the Clematis

Clematis is a hardy plant. In the greenhouse it is subject to but few diseases.

Anthracnose

Caused by *Glœosporium clematidis* Sor.

This disease was first met with by Sorauer * on Clematis Jackmanni in Germany. It is not known whether this disease is present in the United States. Its introduction into this country should be carefully guarded against. Little is known of the causal organism. The disease may be kept in check by the destruction of diseased material.

Leaf Spot

Caused by *Cylindrosporium clematidis* E. and E.

This trouble is manifested as reddish brown subangular to roundish spots on the leaves. The acervuli are immersed, scattered and few in numbers. The conidia are somewhat curved and when ripe exude in a white mass. *C. clematidis*, var. *Jackmanni* E. and E., also found on the clematis, differs from the former in the acervuli exuding a

*Sorauer P., Ztschr, Pflanzenkrank. 7: 230, 1897.

Fig. 51. Broom Rape of Coleus (After Halsted).

black mass of spores which are hyaline when looked at individually.

Coleus

Cultural Considerations same as Geranium, p. 260.

Diseases of the Coleus

Coleus is an unusual hardy plant in the sense that it is subject to so few diseases.

Damping Off

Caused by *Rhizoctonia solani* Kuhn.

It seems that the variegated green varieties are more susceptible to damping off than the variegated red and yellow. Infected cuttings show lesions at the stem and above the surface of the soil. As the lesions spread and work in deeper in the tissue, the cutting topples over. For a description of the causal organism and methods of control, see p. 20.

Broom Rape

Caused by *Orobanche ramosa* L.

Coleus is often subject to the attacks of a broom rape (fig. 51). The trouble was found by Halsted and Kelsey * on greenhouse plants. Orobanche, the broom rape genus, is of interest to greenhouse growers, because of its parasitic nature. Broom rape

* Halsted, B. D., and Kelsey, J. A., New Jersey Agr. Expt. Sta., 23rd Ann. Rept.: 408, 1902.

is a degenerate flowering plant. According to Harshberger,* the embryo of Orobanche has no trace of root and stem, but it consists of a spiral filament of delicate cells which feeds on the stored reserved food of the seed. Upon coming in contact with the roots of a suitable host it adheres itself closely and swells considerably, assuming a flask-shaped appearance. Secondary filaments are now produced from the flask-shaped body which bore in and penetrate into the vascular system of the roots of its host, where it receives its food. At the point of union between host and parasite, a bud is formed which later develops into a thick flower bearing stem which grows out above ground.

The Croton (*Codiæum variegatum*)

Cultural Considerations. Care should be taken not to allow the plants to become pot bound. The best foliage color is obtained when exposed to full sunlight. The plants do well in a moist house with frequent syringing of the foliage. The temperature at night should never be permitted to go down below 70 degrees.

Diseases of the Croton

The Croton is considered a very hardy plant, but one disease is of importance to the greenhouse man.

* Harshberger, J. W., A text book of mycology and plant pathology: 299, 1918. P. Blakiston's Son & Co., Philadelphia, Pa.

Anthracnose

Caused by *Glœosporium soraurianum* All.

Symptoms. This disease is manifested as large yellowish-gray spots on the leaves, which become whitish, dry and brittle with age. The spots are more visible on the upper part, although they work down through the entire thickness of the leaf. The acervuli are usually formed within the spots and become apparent as salmon-colored, gelatinized dots. The causal organism resembles other Glœosporium in structure. *G. soraurianum* is probably the same as *G. crotonis* Del., also found to attack croton leaves.

Cordyline (*Cordyline australis*)

Cultural Considerations. This plant greatly resembles dracenas. Cordylines are usually grown in pots. They require a warm moist atmosphere, and are sensitive to full light. However, during the fall they should be kept drier, and exposed to full light in order to better bring out the color of the foliage.

Fungi Recorded on the Cordyline

The plant is apparently very hardy. The following fungi have been recorded: *Colletotrichum cordylines* Polla., *Macrophoma cordylines* (Thum.) Berl. and Vogl., *Phyllachora vervisegiua* West., *Phyllosticta cordylines* Sacc. and Berl.

CHAPTER 21

CYCLAMEN (*Cyclamen persicum*)

Cultural Considerations. Greenhouse men prefer to sow the cyclamen seed in September and not in spring. In March, the seedlings are transplanted from a two-inch to a four-inch pot and put in a cold frame until large enough to go to a six-inch pot. During the summer, plenty of ventilation and shading should be provided and the plants frequently syringed. In the fall, they are brought into the greenhouse (fig. 52) and some heat provided. The winter temperature should average 55 to 60 degrees F. until the period of blossoming is over. As the leaves turn yellow, the pots are placed in a cool house, water withheld and the period of rest induced. However, a little water is given from time to time to prevent the bulbs from shriveling.

Diseases of the Cyclamen

Cyclamen are subject to but few serious diseases.

Root Rot

Caused by *Thielavia basicola* Zopf.

The disease was reported by Sorauer * as being

*Sorauer, P., Ztschr. Pflanzenkrank. 6: 18, 1895.

FIG. 52.

Type of cyclamen house, to right-hand upper corner, cyclamen anthracnose (after Halsted).

serious in Germany. The general symptoms are the same as for the violets. For a description of the causal organism and general methods of control, see p. 355.

Leaf Spot

Caused by *Glomerella rufomaculans*, var. *cyclaminis* Patt. and Ch.

Symptoms. The spots are circular, watersoaked, with sharply defined borders.

The Organism. The acervuli of the causal organism are brownish, large, conidia straight to slightly curved. Setæ are few, short and rigid. It is very probable that this conidial stage is the same as that described by Halsted as *Colletotrichum cyclamenæ* Hals. The ascus stage was found by Patterson and Charles.* The perithecia are dense, found in definite light colored round spots, brown membranaceous, subglobose with distinct opening. The asci are eight spored, the spores are hyaline, one celled, oblong to elliptic. The methods of control would be the same as for *Colletotrichum cyclamenæ.*

Anthracnose

Caused by *Colletotrichum cyclamenæ* Hals.

Symptoms. Anthracnose produces spots (fig. 52) on the leaves which may be mistaken for the spots caused by *Phoma cyclamenæ.* Infection may occur

*Patterson, F. W., and Charles, V. K., U. S. Dept. of Agr. Bur. Pl. Ind. Bul. 171:12-13, 1910.

at any part of the leaf and spread in all directions. Cyclamen leaves are especially receptive to infection because of the fact that water is able to lodge and remain a long time.

Leaf Spot

Caused by *Phoma cyclamenæ* Hals.

Symptoms. The disease attacks leaves of all ages. The affected portions become darkened. Later the spots become dry and lighter in color, made up of a series of concentric rings of light and dark bands. The dead spots become brittle and drop out at the least touch, giving the appearance of a shot hole. This trouble is different from the leaf spot caused by the *Septoria cyclaminis* Dur. and M. The causal organisms of both of these leaf spots are little known.

Control. Removing the affected leaves and spraying with a standard fungicide will materially assist in keeping the disease in check.

Dracenas (*Dracena fragans*)

Cultural Considerations. The cultural requirements of Dracena are the same as for Cordyline, see p. 247.

Diseases of Dracenas

Dracenas are usually considered a hardy plant. However, they are subject to a few but serious diseases.

Fig. 53. Dracena Diseases.

a. Dracena tip blight, *b.* Phyllosticta leaf spot (both after Halsted).

Leaf Spot and Tip Blight

Caused by *Physalospora dracenæ* Sheld.

The conidial stage as first mentioned by Halsted is a species of Glœosporium. However, the ascus stage was found by Sheldon,* who named it *Physalospora dracenæ.* The disease is generally confined to the tip of the foliage (fig. 53, a.). The affected tissue becomes straw colored and shrunken. The disease may be controlled by spraying with a standard fungicide.

Phyllosticta Leaf Spot

Caused by *Phyllosticta maculicola* Hals.

Dracenæ, particularly the beautiful species *Cordyline terminales*, are often subject to a leaf spot which renders them worthless. The disease attacks plants of all ages and sizes.

Symptoms. The trouble is characterized by small, brown, somewhat angular spots on the leaves (fig. 53, b.). The tissue adjoining the spots becomes yellowish in color. Within these spots may be found minute black bodies (pycnidia) from which the spores, when ripe, ooze out as long colorless tendrils. Little is known of the organism. The disease may be controlled by spraying.

*Sheldon, J. L., Jour. Myc. 13: 138-140, 1907.

Leaf Spot

Caused by *Phyllosticta dracænæ* Griff. and Maubl.

Symptoms. This trouble is manifested as minute, irregular pale spots and bordered by a narrow, brown colored elevated band. The pycnidia are not always present on the spots until the leaves fall off. The spores ooze out as whitish tendrils. This form of spot was first described by Griffon and Maublanc * on greenhouse dracenæ in France. Its extent in the United States is as yet little known.

Leaf Blotch

Caused by *Vermicularia concentrica* Sev.

The thicker-leaved sorts such as Dracena goldiena and the variegated D. Lindemi are often subject to a blotch disease. The trouble is characterized by large, brown blotches on the leaves. Very little is known of the causal organism. Spraying with Bordeaux or any other colorless fungicide may control the disease.

Daffodils

Cultural Considerations, see Tulips, p. 348.

Diseases of the Daffodil

The Daffodil is a very hardy plant. It thrives equally as well in the greenhouse as it does out of doors.

* Griffon, M. M., and Maublanc, Bul. Soc. Mycol. de France 25: 239, 1910.

Yellow Stripe

Cause, improper cultural conditions.

Symptoms. Yellow stripe is a disease which is more commonly met with under field conditions, but also appears on daffodils under glass. The trouble in its early stage is perceptible as a slight discoloration, or a yellowing of the veins of the leaves. In an advanced stage, the leaves become streaked with parallel bands of yellow. In extreme cases, the leaves wither and the plants fail to set blossoms. The disease was studied by Darlington,* who decided that the cause of it is not a parasitic organism, but that it is due to some unfavorable cultural conditions that are as yet undetermined. No methods of control are known.

Erica (*Erica spp.*)

Cultural Considerations. Ericas are low growing evergreen shrubs which lend themselves admirably to forcing on a commercial scale. Too much or too little water is injurious to the plant especially during the blooming period. The plants should never be allowed to wilt. The pots should be renovated every year individually and the proper amount of water given. The plants also need all the ventilation possible.

* Darlington, H. R., Jour. Roy. Hort. Soc. (London) 34: 161-166, 1908.

Fungi on the Ericas

Ericas are apparently very hardy plants. The only fungus known to cause a disease on greenhouse plants is *Stemphylium ericoctonum* Br. and De By. The other recorded fungi are as follows: *Cystospora ericeti* Sacc., *Sporonema obturatum* (Fr.) Sacc., *Trichosporium fuliginosum* Karst.

Ferns

Cultural Considerations. Ferns are propagated by spores, or by division of the clumps. The spores are sown on garden loam over which half an inch of fine sphagnum has been placed. The spores are scattered evenly, and after being sprinkled with water are covered with a glass. In the division of the crowns, they should be planted and kept in a cool house or frame until they make a good start. Most greenhouse ferns thrive best in a temperature of 60 to 65 degrees F.

The following ferns are usually grown on a commercial scale: Adianthum cuneatum and A. gracillinum. Adianthum farleyense seems among the best for decorative purposes. Pteris serrulata is also extensively grown. In large conservatories the tree ferns, especially Alsophila australis, is very much in favor. Of the ferns propagated and sold for dwelling house purposes may be mentioned the sword fern, Nephrolepis exaltata. The latter can stand the atmosphere of a dry room better than any other fern.

Fig. 54.

To left healthy fern plant, to right affected with yellows.

Diseases of the Fern

Ferns as a rule are hardy plants when they are given reasonable care. They are, however, attacked by a few diseases which are of economic importance.

Tip Burn

Cause, physiological.

Ornamental ferns grown in greenhouse or in bay windows are often troubled by a tip burn of the foliage. This is generally confined to the tender new growth. Affected leaflets become brown at the tip, giving the entire leaf an unsightly appearance. There may be various causes responsible for this trouble. An insufficient water supply at the roots will cause the tender leaflets to wilt. If the soil is allowed to remain dry for any length of time, the wilted parts will dry out and become brown. Poisonous gases either from smoke or fumigation will also cause the tender leaflets to dry up and die, thus giving them a burned appearance. Extremes of heat or cold will have a similar effect on the tender tips of the foliage.

Control. It is evident that in this case removing the cause of the trouble will effect a cure.

Leaf Scorch

Cause, physiological.

Symptoms. The trouble appears as prominent

wedge shaped, reddish-brown spots extending inwards from the cleft of the pinnæ. Affected plants take on a variegated appearance and are less luxuriant, but otherwise seem healthy. According to Clinton* the scorching may not necessarily be the effect of burning by the sun's rays. It seems, nevertheless, due to the loss of moisture from drought caused by poor watering or to sudden changes of humidity in the air. The fern Adiantum farleyense is very delicate, and its thin leaves are more sensitive to unfavorable conditions.

Yellows

Caused by overwatering or too much nitrogen in the soil.

Symptoms. Diseased plants lose their green color and turn white. Growth ceases and all leaflets eventually drop off (fig. 54).

Control. In repotting the plant into new soil it outgrows the disease.

Damping Off

Caused by *Pythium intermedium* De By.

This disease attacks young fern prothallia. The latter turn soft, limp, and darker in color than the healthy ones. In general structure the organism resembles *Pythium de Baryanum*. It differs, how-

* Clinton, G. P., Connecticut Agr. Expt. Sta., 31st and 32nd Ann. Rept.: 349-350, 1908.

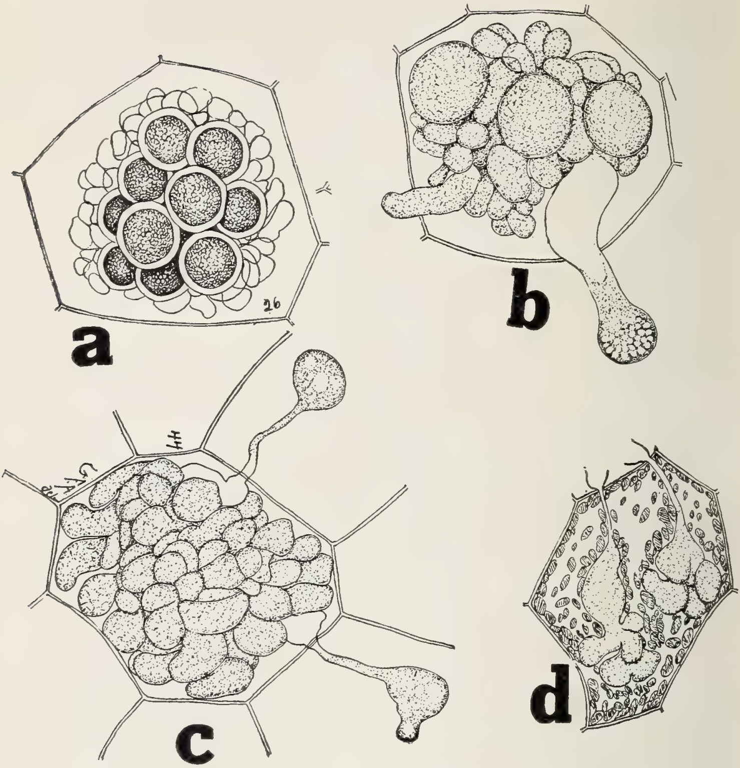

FIG. 55. FERN DISEASES.

a. Host cell invaded with resting spores of *Completoria complens*, *b.* host cell with fungus body of *C. complens*, central cell forming resting spores, and some of the peripheral ones developing conidia, *d.* fungus body in host, the peripheral cells of which develop tubes which penetrate adjacent cells of fern prothallium, *d.* two young plants in one cell of the host, having entered from an adjacent cell (*a-d* after Atkinson).

ever, with regard to the zoospores. As worked out by Atkinson* the zoospores in *P. intermedius* are broadly fusoid, with pointed ends, and terminating at each end in a long cilium. After moving about for five to ten minutes, it gradually comes to a rest, the body undergoing plastic movement until the organism is cut into two parts, forming now two zoospores oval in form and each with a cilium attached directly at the smaller end. This peculiarity makes this organism different from *Pythium de Baryanum*. For control method soil sterilization is recommended (see pp. 32-43).

Completoria Damping Off

Caused by *Completoria complens* Lohde.

Symptoms. The disease attacks young fern prothallia. It is manifested as a yellowish or yellowish-brown color of the prothallia as they lay on the soil in the bed or pot. A careful examination will show that the prothallia are spotted, the spots varying from yellowish-green to yellowish-brown, changing to deep brown and to black. In an advanced stage, a prothallium will present a checkered or mosaic appearance. As rot sets in, the prothallium becomes ragged and torn.

The Organism. The causal organism was studied by Atkinson.† The mycelium of the fungus is made

* Atkinson, G. F., New York (Cornell) Agr. Expt. Sta. Bul. 94: 247-250, 1895.

† *Ibid.*, 252-260, 1895.

up of compact clusters of oval or curved branches originating from a common center. This vegetative bodyoccupiesasingle cell of the affected prothallium, later putting out a slender germ tube which pierces the adjoining intervening wall, forming clusters of oval mycelial branches which become rounded and play the part of resting spores. Each of them may germinate by sending out a short germ tube at the tip of which a conidium is formed. When mature, the latter breaks off and is capable of germinating. Upon coming in contact with the host the conidia germinate by sending out a flask-shaped tube which comes close to the wall of a cell. The protoplasm of the conidium now migrates into the inflated germ tube. The latter produces a slender tube which bores its way into the cell of the prothallium, where it swells and grows in a fashion previously described (fig. 55, a to d.). *Completoria complens* attacks prothallia of the following ferns: Aspidium (Cyrotominum) falcatum, Pterisargyria, and Pt. cretica. Very little is as yet known of its method of control.

Phyllosticta Leaf Spot

Caused by *Phyllosticta pteridis* Hals.

Symptoms. Ornamental ferns, such as *Pteris cretica* var. *Magnifica* are especially susceptible. The first symptoms of the spot disease is loss of the normal green in the frond. This is soon followed by the appearance of the ashy-gray spots surrounded by a border that is either purple or brown. Within the

spot are found minute black pimples, which are really the pycnidia or fruiting sacs of the fungus.

The Organism. Phyllosticta pteridis was first described by Halsted* in 1893. Since that time the fungus has received no further attention from plant pathologists, hence little is known of its life history. It is probable that spraying with Bordeaux mixture will protect the healthy foliage.

Algæ Parasites on Ferns

Caused by species of Oscillatoria.

In damp houses and overwatered soils, the prothalia of ferns are often overrun by certain algæ which chokes them. This is accomplished by shutting out the air and light, interfering with their development and causing them to be completely sterile. As a result, many of the prothalia die. As a control measure, soil sterilization is recommended, see pp. 32-43.

Gardenia (*Gardenia jasminoides*)

Cultural Considerations. Gardenias are very sensitive and easily injured if the temperature falls too low during cold nights. By the end of August, it is advisable to maintain some heat at night so that the temperature may be maintained at about 65 degrees F. The plants require an abundance of ventilation. However, the ventilators should be

* Halsted, B. D., New Jersey Agr. Expt. Sta., Fourteenth Ann. Rept.: 420-421, 1893.

opened gradually in the morning and closed likewise towards the evening. During cloudy days of November and December, care should be taken not to overfeed the plants with liquid manure.

Fungi on Gardenias

Gardenias are apparently very hardy plants. The following are the recorded fungi: *Fumago vagans* Pers., *Hemileia vastatrix* B. and Br., *Hypocrella gardeniæ* Henn., and *Sphærella gardeniæ* Cke.

Genistæ (*Cystisus racemosus canariensis*)

Cultural Considerations. In the fall, the plants are started at a low temperature of about 55 degrees F. The plants are easy to grow and require no special care if proper attention is given to the ventilation and watering.

Diseases of Genistæ

Genistæ are very hardy plants. There is but one disease recorded by Kirchner* on greenhouse plants. The causal fungus is *Ceratophorum setosum* Kirch., which causes a disease on leaves and young shoots of Cytisus.

Geranium (*Geranium sp.*)

Cultural Considerations. Geraniums are mostly grown as a pot plant to be sold for house or out-

* Kirchner, O., Zeit. Pflanzenkrank., 2:324, 1892.

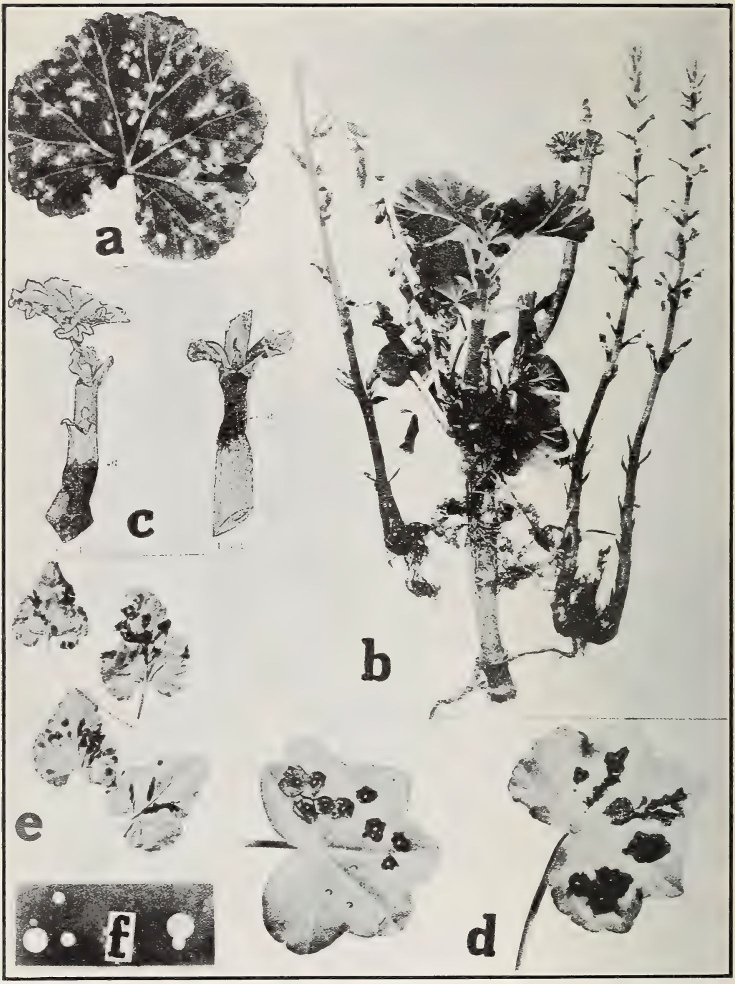

Fig 56. Geranium Diseases.

a. Dropsy, *b.* broom rape (*a* and *b* after Halsted), *c.* bacterial rot (after Galloway), *d-e.* bacterial spot, *f.* colonies of *Pseudomonas erodii* (**d** to *f* after Lewis).

of-doors purposes. Geraniums are easily grown. All they need is a soil fairly rich and an abundance of ventilation. It needs plenty of water, but will rot when overwatered. This is especially true for the cutting bed.

Diseases of the Geranium

The geranium, although a hardy plant, is subject to the attacks of several important diseases.

Dropsy

Cause, physiological.

Symptoms. Dropsy is a serious trouble which is confined to the leaves (fig. 56, a) and petioles and blades. Upon the stems and petioles, it appears as peculiar corky ridges. On the blades, it appears as numerous watersoaked specks of a clear amber color when held up to the light. The disease may attack all the plants in the greenhouse. In this case, the older foliage shows best the watersoaked specks. Such leaves soon lose their normal green color, at first turning yellow in spots, then throughout. In extreme cases, although the affected plant forms the normal number of leaves, they remain dwarfed and puny, and are badly specked before unfolding. Plants spotted lightly often recover when removed out of doors. The disease is worst in the early spring, when it attacks, mostly, young potted geraniums. As a rule, the blotches and pimples are quite

evenly distributed. The specks, however, differ in form. Some are very irregular in outline while others are almost circular.

Cause. Dropsy is favored by poor light, wet soil, and a high soil temperature. Dropsy may be looked for in late winter with long nights, short days and cloudy weather. This causes an excessive root action with results injurious to the plant.

Control. Dropsy may be controlled by providing a cooler, dryer soil, and by exposing the plants to the direction where they will receive the greatest amount of light and ventilation.

Leaf Spot

Caused by *Pseudomonas erodii* Lewis.

Symptoms. This disease was found by Lewis * on greenhouse geraniums in Texas. It is not known how serious or how extensive the disease may appear to be in different parts of the country. It is to be assumed that it is more or less prevalent in every greenhouse where it has been spread about by infected plants or cuttings.

The disease attacks four varieties of ornamental geraniums and the symptoms are the same on all. On the leaves, the spots first appear as minute dots which are transparent through light. With age the spots enlarge, become reddish brown in the center with a colorless border, resembling much the frog eye spot of the apple (fig. 56, d and e.). There

* Lewis, I. M., Phytopath, 4: 221-231, 1914.

is also a tendency to form large spots between the principal veins. In this case, however, infection begins at the margin of the leaf and progresses inwards. Spotted leaves may also become pale and drop off prematurely.

The Organism. Pseudomonas erodii is a short but rather plump rod with rounded ends, borne singly or in short chains of 2 to 3, active by means of polar flagella. It produces no spores, and liquefies gelatin.

Control. There seems no evidence that insects are in any way associated with the spread of the disease in the greenhouse. The causal organism lives in the soil and is spread about by the splashing of water during watering. By the removal of the diseased parts and by careful attention to the watering, the disease may be kept in check. The same disease also attacks the wild geranium, Erodium Texanum, which in this case may act as a carrier of the causal organism. This weed therefore should not be tolerated around greenhouses where geraniums are grown, nor should it be used in the compost soil.

Soft Rot

Caused by *Bacillus caulivorus* Pr. and Del.

Symptoms. This disease was found by Galloway * to be destructive to greenhouse geraniums. It attacks the stems which at first become soft and mushy and later turn black and shrivel (fig. 56, c.).

*Galloway, B. T., Jour. Mycol. 6: 114-115, 1890.

Cuttings are especially susceptible and rotting usually starts at the cut and works upward, destroying it entirely. Rooted cuttings are not as likely to become infected as those freshly made and planted. The disease is most prevalent where young immature cuttings are made, and where the soil has been excessively damp and the house poorly ventilated. Little is known of the causal organism.

Damping Off

Caused by *Pythium de Baryanum* Hesse.

This disease confines its attacks mainly to geranium cuttings. For a description of the causal organism and of methods of control, see p. 17.

Gray Mold

Caused by *Sclerotinia fuckeliana* (De By.) Fckl.

Symptoms. Gray mold is manifested as dead brown spots on the leaves. Under moisture conditions, the gray moldy growth appears. This is but the Botrytis or summer fruiting stage of the fungus. The trouble is prevalent in leaky houses or where water is used in excess and the beds are poorly drained. By proper ventilation, and by careful watering the mold may be kept in check.

Leaf Spot

Caused by *Coniothyrium trabuti* Riza.

As far as is known this disease is not known to

occur in the United States. It was first recorded by Ali Riza * as attacking geranium leaves, causing them to dry and shrivel.

Broom Rape

Caused by *Orobanche minor* J. Esm.

This parasite is frequently met with on clover in the fields. Its attack on greenhouse geraniums was first reported by Halsted.† The seeds of this parasite germinate in the soil. Soon after its roots become attached to those of the geraniums. The growth of the broom rape is soon apparent as a purplish, erect stem with scale-like purplish leaves above the ground. Later a number of blossoms are formed along the unbranched stem. The attacked geranium becomes sickly in appearance (fig. 56, b.). Steam sterilization of the soil will kill the seed of broom rape.

* Ali Riza, Bul. Trimest. Soc. Mycol. France, 28: 148-150, 1912.

† Halsted, B. D., et al., New Jersey Agr. Expt. Sta., Twenty-sixth Ann. Rept.: 509, 1905.

CHAPTER 22

HYACINTH (*Hyacinthus orientalis*)

Cultural Considerations. In forcing (fig. 57, a) hyacinths it is important that they start with a well developed root system. Otherwise the culture is the same as for narcissus (see p. 287).

Diseases of the Hyacinth

The few diseases which hyacinths are subject to are serious. Most of these, no doubt, have been brought in with imported bulbs.

Gumosis

Cause, physiological.

Symptoms. This trouble is characterized by the formation of pure white gum pockets between the epidermis and lower tissue. In this case the starch apparently becomes replaced by gum through a process of degeneration. The gum bearing cells often enlarge abnormally. The true cause of this trouble is unknown, but it is generally attributed to improper culture.

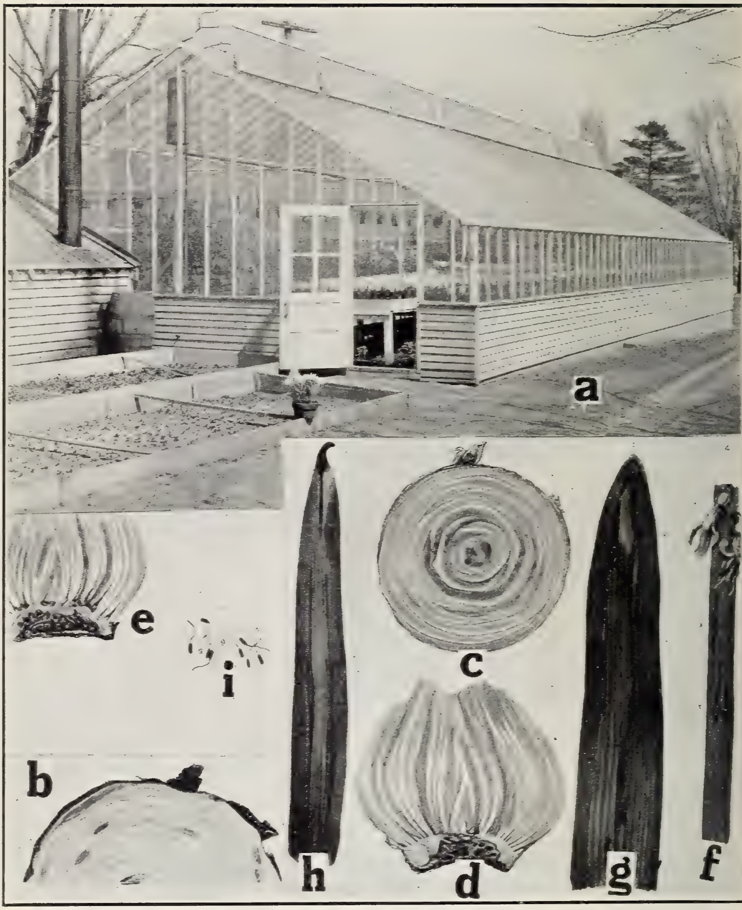

FIG. 57. HYACINTH DISEASES.

a. Type of bulb house, *b-h.* hyacinth yellows, showing type of injury to bulbs, leaves, and blossoms, *i. Pseudomonas hyacinthi* (*b-i* after Smith, E. F.).

Soft White Rot

Caused by *Bacillus hyacinthi septicus* Heinz.

This disease has been studied by Heinz.* Its presence in this country is unknown. Affected bulbs become soft rotted but remain white.

Yellows

Caused by *Pseudomonas hyacinthi* (Wak.) Sm.

Symptoms. This disease as described by Smith † and others is characterized as follows: Early infection becomes apparent as water soaked stripes, soon followed by a yellowing then browning and dying of the affected tissue. The water soaked stripes soon spread all over the foliage, and the accompanying symptoms are the same as previously mentioned. The stripes usually start at the apex of the leaves. Frequently, the stripe runs down the entire length of the foliage while both margins remain green. On the flower stalks the disease is also manifested as a water soaked spot followed by the characteristic browning and shriveling. Infection on the bulb is at first confined to the vascular bundles the latter of which become yellow and gorged with slime. The disease soon spreads, invading and destroying the scales, the latter becoming yellow and soggy. Numerous other invading organisms often enter and

* Heinz, Cent. f. Bakt. 5: 535, 1889.
† Smith, E. F., Bacteria in Relation to Plant Diseases, 2:335-353, 1911.

help to complete the decay and the disorganization of the bulb. Often bulbs are attacked on one side only, in which case the growth of the foliage is also one sided, curved, and bends over towards the diseased side (fig. 57, b to h.).

The Organism. Pseudomonas hyacinthi is a medium sized rod, rounded at both ends, and is actively motile by means of one long polar flagellum (fig. 57, i.). It is non-sporiferous, produces no gas, and liquefies gelatin slowly.

Control. It is fortunate that the disease has not as yet proved serious in the United States. It is a very important disease in the Netherlands, and its introduction with imported bulbs should be guarded against by growers in the United States.

It is very fortunate that there exists a considerable difference of resistance to yellows among hyacinth varieties, as seen by the following list:

RESISTANT		NON-RESISTANT
	Single Red	
Robert Steiger		
Gertrude		
Homerus		
	Single Rose	
Baroness v. Tuyll		Charles Dickens
Moreno		
	Single White	
Grandeur a Merveille		La Grandesse
La Franchise		La Neige
	Single Light Blue	
Grand Maître		Captain Boyton
La Peyrouse		Czar Peter
Regulus		Grand Lilas
		Leonidas
		Lord Derby
		Lord Palmerston
		Orandates
		Queen of Blues
		Schotel

RESISTANT	NON-RESISTANT
Single Dark Blue	
King of the Blues	Argus
	General Havelock
	King of the Blacks
	Masterpiece
	Mimosa
Single Yellow and Orange	
King of the Yellows	Bird of Paradise
Yellow Hammer	Hermann
	Ida
	La citromere
	L'or d'Australie
Double Red	
Princesse Royale	
Double Rose	
Bouquet Royal	
Double White	
Flevo	Florence Nightingale
La Virginité	Grand Vain Queen
	La Tour d'Auvergne
Double Dark Blue	
Crown Prince of Sweden	

In Holland the disease is kept in check by the destruction of diseased plants. Diseased bulbs should never be planted since they will surely introduce the disease in new localities. Spraying in this case will be of no benefit.

Damping Off

Caused by *Dictyuchus monosporus* Seitg.

Symptoms. The above fungus causes a serious damping off, the symptoms of which resemble those of other plants. *Dictyuchus monosporus* is the only one of the genus Saprolginiaceæ which is reported by Halsted as being parasitic on plants.

The Organism. The sporangia are clavate. The swarm spores become walled within the sporangium

and emerge singly through its lateral walls. For methods of control soil sterilization is recommended (see pp. 32-43).

Bulb Rot

Caused by *Rosellinia massinkii* Sacc.

This fungus is reported by Halsted * as thriving on hyacinth bulbs. However, the nature of the injury is not clearly stated by him.

The Organism. The fungus produces dark brown, elliptical spores. The asci are borne in globose or depressed dark colored perithecia.

Sclerotinia Rot

Caused by *Sclerotinia bulborum* Rehn.

Symptoms. The disease is first manifested as yellow stripes or blotches on the leaves and bulbs. With the advance of the trouble, a velvety olive brown mold is formed on the surface of the spots. This growth is but the conidiophores and conidia of the causal fungus. The black sclerotia are developed on the rotted bulbs, and are found mostly within the outer scales. As the sclerotia winter over, they germinate by sending out slender stalks which bear apothecia and ascospores. The Botrytis form of spores is the most prevalent and is depended upon by the fungus to spread it quickly from plant to plant.

* Halsted, B. D., N. J. Agr. Expt. Sta., Fourteenth Ann. Rept. 393, 1893.

Control. Since numerous sclerotia are left in the soil with decayed bulbs, steam sterilization of the soil is recommended. Badly infected bulbs should be removed and destroyed by fire. Plenty of ventilation should be provided whenever possible.

Nematode

Caused by *Tylenchus dipsaci* Kuhn.

Symptoms. This disease was first found in the United States by Byars * on imported hyacinth bulbs. It is prevalent in Europe where it attacks besides the hyacinth, clover, alfalfa, rye, oats, onion, potatoes, and numerous other wild and cultivated plants.

On the leaves, the nematode produces characteristic distortions and yellow to brown longitudinal discolorations. At the end of the growing season, the parasite migrates from the leaves to the scales of the bulbs. Diseased scales become discolored, so that when one cuts through an infected bulb, one or more yellow characteristic rings become very apparent.

The Organism. The adult worm is barely perceptible to the naked eye. It may, however, be readily seen with a magnifying hand lens. Each female produces numerous eggs which hatch into larvæ, the latter of which reach maturity quickly. This means that several generations are produced in one season.

Control. The disease is carried with infected

* Byars, L. P., Phytopath. 4:45, 1914.

bulbs. The latter should therefore be discarded and only healthy ones used.

GRAPE HYACINTH (*Muscari botryoides*)

Cultural Considerations. As soon as the bulbs are brought in the house, they should be given the benefit of the full light, and a low temperature. Neglect in this direction will result in spindly weak plants.

FUNGI OF THE GRAPE HYACINTH

This plant is apparently very hardy. There are but two fungi recorded on this host:

Uromyces scillarum (Grev.) Wint., *Ustilago vaillantii* Tul.

HYDRANGEA (*Hydrangea hortensis*)

Cultural Considerations. Hydrangeas are valuable because of their adaptability to forcing for the Easter trade. Plants should be brought in the early part of January and freed from all old and dead leaves. The beginning temperature should be about 45 degrees F. and after two weeks it should be raised ten more degrees. To force them to flower the temperature is raised to 65 degrees. Ten days before Easter the blooming plants are given a temperature of 50 to 55 degrees. This hardens the blossoms and gives them better keeping qualities. During active growth they need plenty of ventilation, sunlight, and water, and frequent syringing.

Diseases of Hydrangeas

Hydrangeas are very hardy plants. They are subject to but few diseases, which are of little importance.

Rust of Hydrangea

Caused by *Pucciniastrum hydrangeæ* (B. and C.) Arth.

Rust is a serious disease on hydrangeas. The uredinial and tetial stages of the causal organism are doing the damage. Selby * was perhaps the first to have observed the rust, although little more has been added to our knowledge of it or of methods of control.

The Organism. As far as is known *Pucciniastrum hydrangeæ* has only two spore stages, the uredo and teliospores. The uredinia are found scattered mostly on the under side of the leaf, their color dark yellow to pale yellow. The peridium is delicate, the cells are small, while the walls are thin throughout. The ostiolar cells are somewhat elongated, and slightly pointed, the spores are broadly elliptical to ovate; the cell wall is thin and warty. The telia are usually found on the lower part of the leaf in small angular groups, that are rather flat and reddish brown in color. Spores are formed in a single layer within the epidermal cells or immediately beneath it; the cell wall is thin, and a dark, cinnamon brown in color. No methods of control are known. The

* Selby, A. D., Ohio Agr. Expt. Sta., Bul. 214: 402, 1910.

disease may be introduced into the greenhouse with infected plants.

Leaf Spot

Caused by *Phyllosticta hydrangeæ* E. and E.

The disease is characterized by large, rusty, brown spots occurring on the leaves, especially at the edges. The disease is often so severe that it is necessary to cut off the top of the plant. Upon examination of the affected leaves, numerous minute, black pycnidia will be found scattered throughout. The conidia are oblong, hyaline, and one celled, and generally ooze out as minute creamy tendrils. The disease may be kept in check by spraying with a standard fungicide.

CHAPTER 23

LILAC (*Syringia vulgaris*)

Cultural Considerations. Indoor lilacs at first require a cool house. The temperature is gradually increased to about 60 degrees. The plants require frequent syringing and moderate ventilation.

DISEASES OF THE LILAC

Forced lilacs are subject to a few diseases. The plant is generally considered very hardy.

LEAF BLIGHT

Caused by *Pseudomonas syringæ* van. Hall.

Symptoms. The disease as described by Gussow * seems to be confined to the leaves. The writer has found a blossom blight of the lilac both indoors and in the field. In pure culture, the organism resembled *P. syringæ.* The affected leaves become greatly disfigured; the disease spreads very rapidly.

Control. It is doubtful whether spraying will be of any avail. The plants should be given plenty of ventilation whenever possible. Diseased leaves should be destroyed by fire. As far as possible the

* Gussow, H. T., Gard. Chron. 44: 404-405, 1908.

leaves of the plants should be kept dry; all the water should be applied with the hose on the ground, a method that also avoids the splashing of soil particles.

Twig Blight

Caused by *Phytophthora syringæ* Kleb.

This disease was found by Klebahn * to be very serious in propagating beds in Germany. The causal organism attacks and kills the twigs at a distance of several internodes above ground. The flower buds from the affected shoots fail to develop altogether. However, new shoots may appear below the affected area. The disease is of no economic significance in the United States.

Powdery Mildew

Caused by *Microsphæra alni* (Wal.) Salm.

Symptoms. Powdery mildew is perhaps one of the commonest troubles of forced lilacs. The disease is characterized by white powdery patches on the surface of the leaves and stems of the plant. The causal fungus attacks a large number of outdoor plants besides the lilac, as chief of which Lonicera, Alnus, Betula, Quercus, Carya, Castanea, Juglans, and Platanus may be mentioned. Outdoor lilac often suffers greatly from this mildew.

The Organism. The perithecia are either scat-

* Klebahn, H., Krankheiten des Fielders (Berlin): 75, 1909.

Fig. 58. Lily Diseases.

a. Type of lily house, *b*. healthy bulb, *c*. Bermuda disease (after Woods), *d*. Botrytis disease (after Halsted).

tered or crowded greatly, varying in size. This seems also true for the appendages, which vary in length and in numbers, but are rigid, and colorless throughout, excepting the amber brown base, and dichotomously branched at the tips, the latter branches being regularly recurved. The asci are short stalked, ovate to globose; the ascospores are 8 in number.

Control. This mildew may be controlled in the same way as the rose mildew (see p. 323).

Lilies (*Lilium longiflorum*)

Cultural Considerations. The secret of success with lilies is in strong and vigorous bulbs. Lilies forced for the Christmas market should be planted in a rich soil thoroughly mixed with well rotted stable manure. After having been potted, the bulbs should be placed in a cold frame or in a cool dark cellar to encourage the rapid rooting. After that they are maintained at a temperature of 50, then 60, then 75 degrees F. in the house. Lilies for the Easter trade are bought about the middle of December. Lilium speciosum var. rubrum is especially well adapted for forcing.

Diseases of Lilies

Lilies are subject to quite a number of diseases all of which are of economic importance.

The Bermuda Disease

Cause, cultural and mites.

Symptoms. The trouble is characterized by a spotting and distortion of the leaves, flowers, and scales of the bulbs, as well as by a general stunting in growth. In severe cases, there appear yellowish white, longitudinal, sunken spots, and streaks on the first leaves as they show above ground. As growth proceeds each succeeding whorl becomes similarly affected, and finally collapses and dries. Even the flowers become spotted, shrunken, and distorted. Occasionally plants appear healthy, until the disease suddenly breaks out on the flowers. It is seldom that all the leaves in the same whorl are uniformly affected (fig. 58, b and c.). The diseased foliage or whorls may be irregularly scattered along the main stalk. The greatest damage occurs when the flowers are spotted, since the plants become unsalable whether the leaves are healthy or not.

Cause. There are many current theories as to the cause of the disease. Some growers believe that it is due to soil exhaustion. Others believe that it is due to the removal of the flower stalks by the growers in Bermuda, who desire to sell them, thus giving them a double source of profit. It is claimed that this practice weakens the bulbs by depriving them of their proper nourishment. Still others are of the opinion that the bulbs become weakened by being harvested prematurely. Finally some growers hold that the trouble is due to an insect which feeds on

the scales of the bulbs. The investigations by Woods * have shown that the trouble is brought about by a combination of causes. Poor cultural conditions such as overwatering, or the use of poor, unselected bulbs will generally and indirectly tend to cause this disease. The bulbs may be further weakened by the attacks of a mite (*Rhizoglyphus echinops*) and of certain fungi and bacteria. The bulbs may also become weakened by allowing the roots to dry and then overwater.

Control. The disease cannot be cured. The best that can be done is to select strong, healthy bulbs. Crop rotation to prevent the spread of the mite is also recommended.

Rust

Lilies are subject to several rust diseases. The most important is the American rust and is caused by a species of *Uromyces.* This disease according to Halsted † was first found on leaves of Lilium candidum at Buffalo, N. Y.

The Botrytise Disease

Caused by Botrytis sp.

Symptoms. The trouble is apparent as small rusty spots upon the buds, leaves, and blossoms.

* Woods, A. F., U. S. Dept. of Agr. Div. of Veg. Phys. and Path. Bul., 14: 7-15, 1897.

† Halsted, B. D., New Jersey Agr. Expt. Sta., Fourteenth Annual Rept.: 392, 1893.

With the advance of the disease, the spots become coated with a fuzzy, brownish coat, made up of the fruiting stalks. As the plant becomes decayed, numerous sclerotia appear. The disease is spread in the hothouse through the watering or in syringing. Infection is favored by a high humidity and poor light conditions in the house. Little is known of the causal organism (fig. 58, d.).

Control. The disease may be kept in check by proper ventilation.

Calla Lily (*Araceæ spp.*)

Cultural Considerations. The yellow callas are grown in the same way as the white callas except that they seem to do better without a rest period. White callas require a rich soil, full sunlight and an abundance of water during the growing season. During the summer, the plants undergo a resting period. The pots are laid out in the open in the shade and a little water is given occasionally to prevent the Rhizomes from drying out.

Diseases of the Calla Lily

Callas are apparently a hardy plant. It is subject to but few diseases.

Soft Rot

Caused by *Bacillus aroideæ* Town.

Symptoms. This disease may be found both on

calla lilies in the greenhouse or in the field. The callas usually rot off at or below the surface of the ground, the disease frequently spreading downward in the direction of the corms and upward into the leaves. Occasionally soft rot starts at the edges of the leaves or at the flower stalk. The disease spreads more rapidly and is also worse in greenhouses where callas are grown in solid beds.

In cutting open a diseased corm, one observes a line of demarkation between the healthy and diseased tissue, the latter being brown, soft, and water soaked. Affected leaves become slimy without necessarily losing their green color. If the disease attacks flower stalks, the flowers turn brown and the stalk falls over although its green color is preserved. As the disease progresses under ground the plant above ground topples over without any sign of disease. Under unfavorable conditions, the disease in the corm may not progress further than a small spot which soon dries. The causal organism, however, remains alive in these spots, but dormant until the time when conditions of moisture and temperature again become favorable. The nature of the soil determines to a large extent the severity of the rot. A soil rich in humus is most favorable for its spread.

The Organism. Bacillus aroideæ is a short rod with rounded ends, single or in chains of two or four. Its growth is white on solid media. It produces no gas, and liquefies gelatin. Although apparently distinct from *Bacillus caratovorus* Jones, it is nevertheless capable of producing a soft dark colored rot in

carrot, potato, turnip, radish, cabbage, cauliflower, tomato, and in the fruit of eggplant and cucumber.

Control. The disease may be prevented from getting a start by discarding diseased or spotted corms. Changing the soil every third or fourth year, or steam sterilizing it will prevent infection of the healthy corms. Starting the plants in pots instead of planting them directly in the beds is also recommended. In this way, all diseased plants will be discarded before being put finally in the bed.

Blight

Caused by *Phyllosticta richardiæ* Hals.

Symptoms. This disease is characterized by large, ashy spots on the leaves. Within these spots may be found minute, dark fruiting bodies (pycnidia). Very little is known of the causal organism. Blight may often be confused with a spotting due to sunscald. In this case, however, the dead tissue is invaded with the fungus *Pestalozzia richardiæ* Hals.

Leaf Blight

Caused by *Cercospora richardiæcola* Atk.

Symptoms. This disease was first found by Professor Atkinson in Alabama in 1891. The spots are black with small white centers, and may be formed on all parts of the leaves.

The Organism. The conidia are hyaline, and from 4 to 10 septate. The conidiophores are borne in

bundles and are brownish to reddish in color, finally becoming reddish brown with age.

Control. This disease may be kept in check by spraying with a standard fungicide.

Japan Lily Disease

Caused by *Rhizopus necans* Mass.

Symptoms. This disease is characterized by a soft rot of lily bulbs, especially Lilium speciosum, and L. auratum. The malady was studied by Massee * who found it on imported bulbs from Japan. The causal organism seems to be a wound parasite, that gains entrance to the roots through a wound. From the roots, it works its way up to the scales and causes them to rot. Diseased bulbs generally become covered by a white weft of mycelial growth which is soon followed by numerous clusters of sporophores bearing black globose sporangia.

The Organism. The mycelium is white, the sporophores forked or simple. Sporangia globose, blackish to deep brown, columella large. Spores striated, pale olive. Zygospores dark, and covered with spiny warts.

Control. Where the disease occurs once, the soil should not be used again unless it has been sterilized with steam or formaldehyde. Injured bulbs should not be planted. In shipping bulbs, care should be taken that they are not packed damp.

* Massee, G., Diseases of Cultivated Plants and Trees: 133, 1910 (Macmillan Co., New York).

Blight of the Variegated Plantain Lily (*Funkia Undulata.* var. *Variegata*)

Caused by *Colletotrichum omnivorum* Hals.

Symptoms. This blight is severe on the broad and the narrow leaved varieties, and especially on Funkia undulata var. variegata. The disease appears as spots at about the middle of the leaf. The tissue in these soon drop out, leaving the veins which run lengthwise. Badly diseased foliage have a shredded appearance. The same disease also attacks Aspidistra lurida var variegata, a plant closely related to the Funkia. At present, little is known of the nature of the causal organism.

Control. Halsted * recommends spraying with Ammoniacal copper carbonate. Attention should be paid to securing resistant varieties.

Lily of the Valley (*Convalaria majalis*)

Cultural Considerations. This plant may be forced at any time of the year. Sand is the best soil in which to grow it. It is advisable to begin with a bottom heat of 50 degrees F. and quickly raise it to 85 degrees. The plants require an abundance of water during the forcing period.

Diseases of the Lily of the Valley

Lily of the Valley is considered a hardy plant. They are however known to suffer from two diseases.

* Halsted, B. D., New Jersey Agr. Expt. Sta., Thirteenth Ann. Rept.: 296, 1892.

Rot

Caused by *Botrytis pæoniæ* Oud.

This disease, which is usually common on peonies and on lilacs, also frequently attacks the lily of the valley. The causal organism often attacks the pips first; then works its way up to the stems. Infected pips become soft, then become covered with a grayish mold, and are later peppered with greenish-black, flat sclerotia.

Control. The disease is often introduced with infected pips which have been previously injured, or kept under poor storage conditions, especially under too high temperatures and moistures. Hence only healthy pips should be used. If the soil becomes infected with the causal organism, it should be steam sterilized, or treated with formaldehyde (see pp. 32-43) the former method being preferred.

Leaf Spot

Caused by *Dendrophoma convallariæ* Can.

This leaf spot often destroys entire beds of plants. Little is known of the causal organism or of methods of control.

Septoria Leaf Spot

Caused by *Septoria majalis* Aderh.

This disease is characterized by a general spotting which is unevenly scattered over the leaves. The spots, however, are found mostly on old and faded

leaves, hence the trouble is of no economic importance.

Mignonette (*Reseda odorata*)

Cultural Considerations. The soil required for mignonette is about the same as for carnations. Raised benches are preferred rather than pots. An inch of well rotted stable manure is placed at the bottom, and four inches of the compost on top. Young seedlings require an abundance of ventilation. During bright weather temporary shading is necessary. Mignonette is very sensitive to overwatering. The watering should be done in the morning. If water remains on the foliage over night, the plants will become badly spotted. The temperature of the house in cloudy days should not run above 55 degrees F. and in bright days not higher than 65 degrees.

Diseases of the Mignonette

Mignonette is subject to but few diseases. The most important of these may be mentioned as follows:

White Rust

Caused by *Cystopus candida* (Pers.) Roussel.

This disease is commonly met with out of doors on practically all cultivated cruciferous plants. In Europe, white rust seems to attack the mignonette, but there are no records of similar cases in the United States.

Leaf Spot

Caused by *Cercospora resedæ* Fl.

Symptoms. The trouble becomes apparent as minute pale spots with yellowish to brownish borders. In spreading over the entire leaf, it takes on a reddish discoloration. Usually, the lower leaves are most affected. Little is now known of the causal organism.

Root Rot

Caused by *Rhizoctonia* sp.

Root rot of mignonette may be expected wherever the soil in the benches is infected with Rhizoctonia. The young plants usually damp off. Older ones rot at the base of the stem and at the roots. In either case, affected plants are dwarfed, and the leaves have a sickly yellow color. For a description of the organism and for methods of control, see p. 20.

Narcissus (*Narcissus bulbocodium*)

Cultural Considerations. Narcissus is easily forced. After potting, a thorough watering should be given, as the bulbs fail to set roots in a dry soil. The pots should be placed in a cool cellar to encourage root formation and to retard top growth. After bringing the pots into the greenhouse, they should at first be placed under the benches or under subdued light, and in a low temperature of about 50 degrees F. Later the plants are gradually ex-

posed to more light. The more slowly they are forced the better the quality of the flowers. During the blossoming period great care should be given to the watering. At no time should the root system be permitted to become dry. On bright days the tops of the plants should be syringed until the flowers begin to show color.

Diseases of the Narcissus

Narcissus under normal care is very hardy and subject to very few diseases.

Rust

Caused by *Puccinia schrœteri* Pass.

This rust often attacks Narcissus poeticus. It is of no economic importance in the United States.

Bulb Rot

Caused by *Fusarium bulbigenum* Mass.

Symptoms. This trouble, which was studied by Massee,* is said to be prevalent in England. Its presence in the United States has not been reported. The trouble first appears on the leaves as small yellowish spots. These, however, enlarge and work downward into the bulb scales, the latter of which soon rot. The disease is spread by partly diseased

* Massee, G., Roy. Bot. Gard. Bul. Misc. Inf.: 307-309, 1913.

bulbs and through infected soil. Little is now known of the causal organism.

Control. Care should be taken to prevent the introduction of this disease into this country. All bulbs which show the least discoloration should not be used for planting.

CHAPTER 24

ORCHIDS (*Orchidaceæ*)

Of the numerous orchids, the following are the important commercial genera with their cultural requirements:

Culture of Calanthe

These are easily grown in pots or in beds, about one-third space being devoted to drainage by means of a layer of clean sphagnum. The pseudobulbs are then planted in a compost which is made up of one-third chopped sod with the fine soil removed, one-third chopped live sphagnum and leaf mold to which charcoal is added as a sweetener. Calanthes require a winter night temperature of about 50 to 55 degrees and a day temperature of 65 to 70 degrees F. The plants require an abundance of water during the growing period, but less when the leaves start to drop and blossoming begins. At this stage, only enough water is needed to keep the blossoms from wilting. When the blossoming season is over the plants are given a six weeks' rest. The pots with the pseudobulbs are laid on the side in a dry warm place and the soil kept dry.

Culture of Cattleya

These plants require perfect drainage conditions. They thrive best in osmunda fiber pots. On a commercial scale, it is not desirable to cover the plants with moss as this usually harbors slugs which are fond of the blossoms. Cattleyas require frequent syringing with the hose. The temperature required is the same as that for Calanthe. After flowering the pseudobulbs need a rest. In this case they require enough water to prevent them from drying. Cattleyæ thrive best when grown near the glass.

Culture of Cœlogyne

The cultural requirements are the same as for Cattleyæ, the pot culture, however, being preferred. The plants are heavy feeders, hence weak manure water may be applied once every week during the growing season. After flowering the plants are repotted and kept in a cool house until about September.

Culture of Cypripedia

These plants require no rest period, hence may be grown the year round. They require a winter night temperature of 60 to 65 degrees F. and a day temperature of about 70 degrees F. As spring approaches a higher temperature may be given, and the glass lightly shaded. However, in the winter the plants require the full sunlight.

Culture of Dendrobium

These plants seem to thrive best in small pots or baskets. They also require an abundance of water during the growing season, and a night temperature of about 65 degrees F. When flowers appear the plants become destitute of leaves, at which time only enough water is applied to prevent the pseudobulbs from drying.

Culture of Lælia

These plants require a sunny location and an abundance of overhead water during active growth.

Culture of Lycaste

These plants need to be kept as cool as possible in the summer; otherwise, the culture is the same as for Cattleya.

Culture of Odontoglossum

These plants require an abundance of ventilation, and a cool moist temperature during the summer. They are grown in pots or baskets filled with soil made of equal parts peat, live sphagnum moss, and osmunda fiber.

Culture of Oncidium

These plants require a bright, warm house and are suspended from the rafters in small baskets.

Culture of Phalænopsis

These plants require plenty of ventilation, but too much of it should be avoided. Frequent syringing is necessary and the temperature requirements from 70 to 75 degrees F. at night and about 90 to 95 degrees during the daytime.

Culture of Vanda

These plants require shade after February. They prefer a night temperature of 65 degrees F. and seem to thrive best in baskets near the glass.

Spot Disease of Orchids

Cause, mechanical injury.

Symptoms. This disease is manifested as minute pale spots on the upper side of the leaf. The spots vary considerably in size, arrangement, and numbers, and may occur on any parts of the foliage irrespective of age. The trouble may be easily overlooked, due to the light color and the superficial nature of the spots. With age, however, the spots may go through the entire tissue of the leaf. The cause of the trouble, as explained by Massee,* is of non-parasitic origin. It is brought about by the presence of minute drops of water on the surface of the leaves during very low temperatures while the roots are too copiously supplied with water. The

* Massee, G., Annals of Bot. 9:422-429, 1895.

water drops produce a chill which causes the content of the underlying cells to plasmolyze. This is followed by the precipitation of tannin and the disintegration of the cells. The method of control would consist in the careful watering of the plants during cool weather.

Orchid Deterioration

Cause, cultural.

Florists are aware of the fact that imported orchids often run out and deteriorate after a year or two of culture under glass. Attention has been called to a similar trouble by Truffant and Hebert.* They maintain that deterioration is due to an increase in the percentage of mineral matter and a decrease in the percentage of nitrogen in the deteriorated plants. The trouble, it is believed, is due largely to improper nutrition under cultivation.

Leaf Spot of Orchids

Cause unknown.

This disease is often found on hybrid Calanthes. It is manifested as large and small dead patches on all the parts of the plant. The leaves especially become unsightly, and as a result the blossoms are small and stunted. This disease was first described by Bidgood † on greenhouse hybrid Calanthes. The

* Truffant, G., and Herbert, A., Jour. Soc. Nat. Hort. France, 19: 85-98, 1897.

† Bidgood, J., Jour. Roy. Hort. Soc. 29: 124-127, 1904.

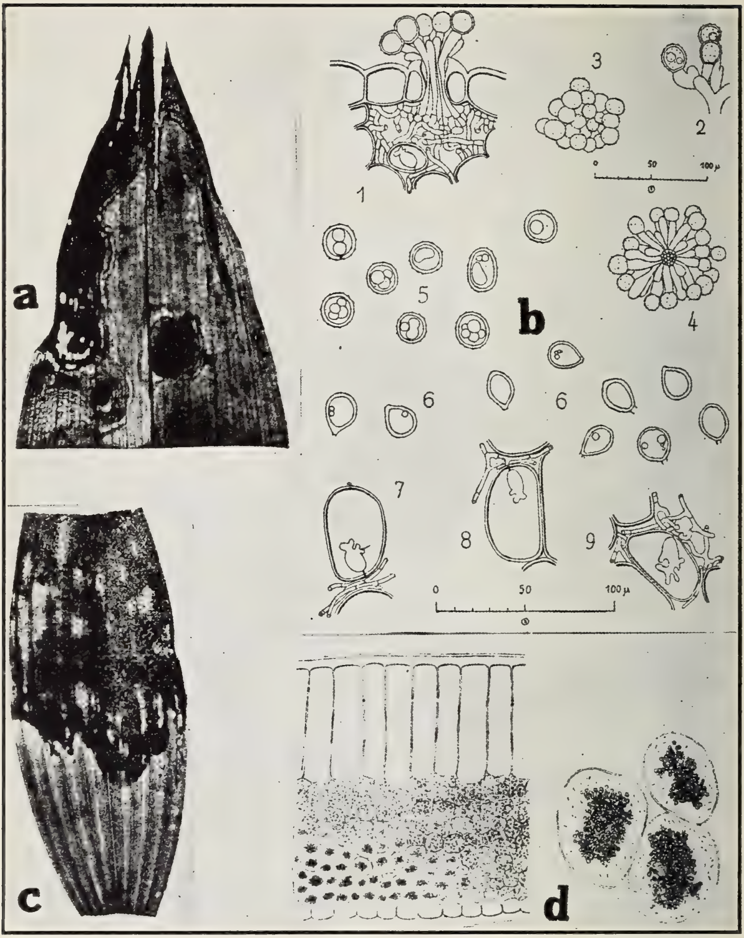

FIG. 59. ORCHID DISEASES.

a. Volutella blight of Bletia (after Halsted), *b.* rust, *Hemileia oncidi* (after Griffon and Maublanc), *c.* Sobralia anthracnose (after Halsted), *d.* bacterial leaf spot, partly diseased leaf with cells invaded by the organism (after Hori, S.).

cause of the disease and methods of control are as yet unknown.

Bacterial Leaf Spot of Orchids

Caused by *Bacillus cypripedii* Hori.

Symptoms. According to Hori,* this disease is prevalent in Japan and is greatly feared there. The disease attacks the most valuable orchids and ruins them in a very short time.

The disease is manifested as light amber-colored spots on the leaf blades. The spots quickly enlarge, and in a few days the entire leaf becomes invaded and discolored. A few days later the diseased foliage turns brownish and later a deep chestnut brown; the upper surface becomes wrinkled, with loss of luster. The lower surface of the leaves, just underneath the spots, rapidly take on a faintly pale color, and only gradually assumes the same color as that of the upper part. If infection takes place on the lower portion of the leaf, the upper half soon becomes yellowish and dies off as a result of lack of food (fig. 59, d.). The rot from the leaves works down to the stem, involving the entire plant.

The disease (also known as brown rot, brown spot) attacks orchids with fleshy, succulent leaves, such as Phalænopsis amabilis, Ph. schileriana Cypripedium haynaldium, C. philippinense, C. lævigatum, C. godefroyæ. The more susceptible varieties seem to be Phalænopsis schilleriana and Cypripedium

* Hori, S., Centralb. fur Bakt., 31:85-92, 1911.

phillipinense. Infection takes place by means of a wound.

The Organism. Bacillus cypripedii is a medium sized slender rod-shaped organism, rounded at both ends, occurring in chains of 2-3, and motile by means of flagella. On agar it forms a smooth, light grayish white colony with a pearly luster, and a dirty cream-colored growth on potato plugs. It produces a film on bouillon, coagulates milk, and rapidly dissolves gelatin. It is not known whether the causal organism is the same or closely related to the one described by Peglion * under the name of *Bacterium oncidii* Peg. as causing a disease on orchids. Very little is known of the methods of control. Since infection takes place through a wound, care should be taken to prevent careless washing with a rough sponge. Diseased material should be destroyed by fire.

Rust of Orchids

Caused by *Hemileia oncidii* Griff and Maubl.

Symptoms. The disease is characterized by minute yellowish spots, the surfaces of which become covered with an orange-colored powder which is made up of the spores of the causal organism. The spots enlarge, the center turns brownish, while the advancing margin remains an orange rust color. The disease was first described by Griffon and Mau-

* Peglion, V., Centralbl. für Bakt. 5:33, 1899.

blanc,* who found it on orchids in greenhouses in France. It is not known whether this rust is of any importance in the United States. The only danger consists in its being imported from abroad with imported plants. The causal organism produces only teleutospores. It feeds on its host by means of haustoria sent into the interior of the cells (fig. 59, d, 1-9.).

Rust of Orchids

Caused by *Uredo behnickiana* Henn.

Symptoms. This rust does not produce any striking symptoms. Hence it may readily be overlooked. Affected leaves are covered with minute, reddish-colored sori. When mature, the epidermal covering of these sori breaks away and liberates a reddish powder which is made up of thousands of the spores of the fungus. This rust is found on living leaves of Oncidium dasystelis and was described by Hennings † as a serious disease of orchids imported to Germany from Brazil. It is not known whether this disease is present in this country. Its introduction should therefore be guarded against. *Uredo behnickiana* differs from *U. onicidii* Henn, in that the latter causes rounded thickened red-brown spots on Oncidium lavecanum.

* Griffon, M. M., and Maublanc, Bul. Soc. Mycol. de France 25: 135-139, 1909.

† Hennings, P., Hedwigia 44: 169, 1904.

Petal Blight

Caused by *Sclerotinia fuckeliana* (De By.) Fckl.

Greenhouse growers are often troubled with a petal blotch of orchids. This disfigures the blossoms, and consequently ruins their market value. The disease appears as small spots over the entire surface area of the petals. Frequently the spots are bordered by a delicate ring of pink. Perhaps another stage of this disease is marked by the large spots which cause the petals to become disorganized. Affected petals either drop off or stick to the now worthless blossom. On examination of the spotted petals, there will be noticed a gray mold growing on the surface of the affected tissue. This is but the fruiting stalks of the causal organism. This gray mold will also be found on faded blossoms, and if allowed to remain in the greenhouse will saturate the place with the spores of the fungus.

Control. All affected blossoms should be cut off and destroyed. This simple precaution will remove the host upon which the fungus is able to thrive as a saprophyte.

Rot

Caused by *Nectria bulbicola* Henn.

This trouble is manifested as a rot on the pseudo bulbs of Macillaria rufescentis. It was originally found by Hennings* on orchids brought in from Venezuela or Trinidad.

* Hennings, P., Notizbl. K. Bot. Gasten u. Mus. Berlin.

There are other Nectria recorded on orchids: *Nectria vandæ* Wahrl on root of Vanda suavis, *Nectria goroshankianna* Wahrl., *Nectria* (*Dialonectria*) *binotiana* Sacc., and *Nectria* (*D.*) *phyllogena* Sacc. on leaves of epiphyte orchids in Brazil.

Anthracnose of Orchids

Caused by *Physalospora cattleyæ* Maub. and Las.

Symptoms. This trouble is manifested as yellowish light spots the tissue of which becomes soft. When the epidermis is torn away from one of the spots a clear liquid will ooze out. At this stage of the malady infected leaves lose their normal color, collapse, and drop off. Ordinarily there is no fruit of any fungus formed on the spots, but under moist conditions the acervuli of the causal fungus appear. The disease, although attacking the foliage, does its greatest damage to the stems. Infection can take place only through a wound made in the epidermis.

The Organism. It is only the summer stage of the fungus, *Gloeosporium macropus* Sacc., which causes the disease on orchids. The same stage also produces a similar disease on foliage of Haya carnosa, Citrus aurantium and Aloes. Its occurrence on orchids was called attention to by Mangin,* who found it to be a serious disease of greenhouse orchids

* Mangin, M. L., Jour. Soc. Nat. d'Hort. de France 19: 449-452, 1897.

in France. It is doubtful if it is yet to be feared in the United States.

Control. Care and vigilance should be exercised to prevent the introduction of the disease to the United States. All infected material should be destroyed by fire and the plants should be sprayed with a standard fungicide.

American Anthracnose

Caused by *Glomerella cincta* (B. and C.) S. and S.

The American anthracnose is very prevalent on hothouse orchids. The variety most susceptible to the disease is Sobralia macramtha. The trouble is first noticed by a discoloration on the stems which soon become brown almost to black while the tender interior tissue becomes soft and decayed. Later the spore pustules appear in great abundance on the dead parts. On the leaves the disease works in a way similar to that found on the stems. The trouble, however, nearly always starts from the tip and works downwards (fig. 59, c.). There is usually a distinct line of demarkation between the healthy and the diseased tissue.

The Organism. The conidial or summer stage of the fungus was described by Halsted.* The conidia are elliptic and guttulate. Setæ may often be present, but they are generally obscured by the

* Halsted, B. D., New Jersey Agr. Expt. Sta., Fourteenth Ann. Rept.: 414-415, 1893.

great masses of spores formed in the acervuli. The ascus or winter stage was discovered by Stoneman.* The perithecia are flask-shaped, the asci are clavate. The ascospores vary from elliptic to curved in shape.

Control. Before attempting anything else, the source of infection should be removed. All infected plants should be destroyed by fire. Spraying with Bordeaux mixture 4-4-50 will help to protect the plants from becoming infected.

Bletia Anthracnose

Caused by *Colletotrichum bletiæ* Hals.

The beautiful Bletia orchid is often subject to the attacks of an anthracnose, the cause of which is due to a closely associated organism of the Sobralia anthracnose. On the Bletia, the trouble is manifested as a spotting that disfigures the leaves and reduces their usefulness. The spots are almost black and very soft. As this disease progresses, the soft tissue rots and breaks away the fibrous portions. Usually the trouble begins at the tender tips, and causes affected foliage to have a ragged appearance.

The Organism. In structure the organism resembles other Colletotrichums. The acervuli are light brown in color and possess numerous dark setæ.

Control. The trouble may be kept in check by spraying with Bordeaux mixture. It is also essential to destroy by fire all dead and diseased material

* Stoneman, B., Bot. Gaz. 26: 69-120, 1898.

and to prevent them from finding a place in the manure or compost pile.

European Anthracnose

Caused by *Glœosporium affine* Sacc.

This disease has been reported by Sorauer* as very serious on cultivated orchids. The trouble is prevalent in overheated hothouses and on plants which have been excessively fertilized.

Symptoms. On the leaves, anthracnose causes a discoloration and a drying which starts at the tip, or at the periphery or border. Usually the youngest foliage is attacked first. In severe cases, the older leaves and even the bulbs become diseased, wither, and dry up. The disease is carried about with infected bulbs. The same trouble also attacks other orchids such as Cattleya Mendelii and Cypripedium lævegatum.

The Organism. In structure, *Glœosporium affine* differs very little from other Gleosporiums. The fungus attacks the epidermis, then works into the mesophyllic layer of cells, where the chloroplasts are destroyed. This explains the disappearance of the green coloring matter in the affected parts. The spore pustules are formed under the epidermis, the latter bursting as the spores accumulate. The spores are formed on what appears to be a pseudostroma. The spores are one-celled, hyaline, cylindrical, and

* Sorauer, V. P., Zeitsch. Pflanzenkr. 21: 387-395, 1911.

often slightly curved. The spores germinate quickly, usually after forty-eight hours. *Glœosporium affine* is troublesome on orchids in Europe, but has not yet proved very serious in the United States.

Other Orchid Glœosporiums

Glœosporium oncidii Oud. = *G. maxillariæ* All. This organism is confined to leaves of Maxillaria infestans.

Glœosporium epidendri Henn. This organism attacks stems of Epidendrum sp.

Glœosporium stanhopeæ Allesch. is found on leaves of Stanhopeæ.

Glœosporium læliæ Henn. is found on leaves of Lælia sp.

Glœosporium pallidum Karst. and Har. occurs on leaves of Liparis longipes.

Colletotrichum orchidearum K. and H. appears on leaves of Bolbophyllum labbi, B. longiflorum. It is also found on foliage of Cymbidium sp., Physiophon loddigesii; Ezia stelleta, Cœlogyne mayeriana, Pleurothallis tribuloides, Sarcanthus pugioniformis, on pseudobulbs of Eulophia saundersiana and on Oncidium pulvinatum.

Colletotrichum dicheæ Henn. grows on foliage of Dichæa vaginata.

Colletotrichum roseolum Henn. develops on the pseudobulbs of Stanhopea oculata.

Leaf Spot of Orchids

Caused by *Cercospora angreci* Roum.

Symptoms. This disease is usually manifested as spots which are more prominent on the underside of the leaves. As the affected foliage turns pale and loses its green color, the spots become covered with a chocolate-colored mold. The latter growth consists of the fruiting stalks and conidia of the fungus. *Cercospora angreci* is found on foliage of Odontoglossum alexandræ. Little is now known of the causal organism and of methods of control.

Bletia Leaf Spot

Caused by *Volutella concentrica* Hals.

Associated with the anthracnose *(Colletotrichum bletiæ)* is often found a leaf spot which may be mistaken for it. The characteristic of this disease is the formation of large dark spots (fig. 59, a.). Each spot is made up of numerous bluish-colored concentric rings. The fruitings of the fungus appear as lemon-colored balls. It is not definitely known whether the Volutella fungus is an active or a weak parasite merely following some injury, or the attacks of a bacterial organism. In fact little study was given to this trouble and the only record that exists is a note by Halsted.*

* Halsted, B. D., New Jersey Agr. Expt. Sta., Fourteenth Ann. Rept.: 417, 1893.

Fungi Found on Orchid Leaves

The following are fungi found by Hennings* on dead orchid leaves:

Physalospora orchidearum Henn. This fungus is found on dead stems of orchids of Tainiæ stellatæ and Lælia schilleriana. It is probable that the fungus *Physalospora herbarum* (Pers.) Rab. found on dead stems of Phajuswallichii is the same as *P. orchidearum.*

Pleospora orchidearum Henn. This fungus is found on dried-up stems of Phajuswallichii.

Nectria (*Dialonectria*) *bolbophyli* Henn. This fungus is found on dead pseudo-bulbs of orchids of Bolbophyllum lobbii.

Nectria behnickiana Henn. This was found on orchids imported from Brazil.

Macrophama oncidii Henn. This fungus was found on dead leaves of Oncidium pulvinatum.

Macrophoma cattleyicola Henn. This fungus was found on pseudo-bulbs of Cattleya labiata.

Diplodia sobraliæ (Henn.) Taub.† Found on dead leaves of Sobralia sessilis.

Other Fungi Found on Orchids

Stibella bulbicola Henn. is found on pseudo-bulbs of Gomeza plantifolia, Stanhopea spec., Sarcanthus pugioniformis, Epidendrum spec. and on Oncidium pulvinatum.

* Hennings, P., Hedwigia 44: 169-174, 1904

† See Taubenhaus, J. J., Amer. Jour. of Bot. 2: 324-331, 1915.

Graphium bulbicola Henn. occurs on pseudo-bulbs of Oncidium pulvinatum.

Tubercularia cattleyicola Henn. grows on stems of Cattleya guttata.

Sclerotium orchidearum Henn. develops on stems of Vanda tricolor, and Dichæa vaginata.

Diplodia bulbicola Henn. Found on dead pseudo-bulbs of *Gomeza planifolia.*

Zythia nepenthis Henn. Found on dead leaves of *Nepenthes bicolorarta.* Of the other fungi which are often found on dead foliage of Nepenthes may be mentioned *Phyllosticta nepentheacearum* Tassi, and *Phoma nepenthis* Cook and Mass. *Humaria thozetti* Berk., *Excipularia epidendri* Henn. Found on dead foliage of Epidendron.

Oxalis (*Oxalis bowiei*)

Cultural Considerations. Oxalis is forced mainly as a window plant grown in baskets or pots. It requires a rich soil and an abundance of water. The flowers open only when exposed to full light.

Fungi Recorded on Oxalis

The Oxalis is a very hardy plant. The following are the fungi recorded on the host: *Æcidium oxalidis* Thuem., *Darluca filum* (Biv.) Cast., *Puccinia oxalidis* Diet. and Ell., *Urocystis oxalidis* Pazs.

Palm (*Phœnix spp.*)

Cultural Considerations. Palms are very sensitive to wet and poorly drained pots or benches.

Fig. 60. Type of Palm House.

The soil best suited to palm culture is that which is made up of two-thirds rotted sod and one-third well rotted cow manure. Palms do poorly when treated with commercial fertilizers, and when its root system is disturbed, hence they should be repotted only when absolutely necessary. Palms love partial shading (fig. 60) and a moist atmosphere. The temperature should be allowed to go below 60 degrees F. at night. The foliage should be kept free from dust.

Diseases of Palms

Forced palms are subject to less disease than those grown out of doors. Nevertheless, some of these indoor diseases often become very troublesome and serious.

Smut

Caused by *Graphiola phœnicis* Port.

Symptoms. Smut is a common disease on both greenhouse and outdoor palms of all sorts. The affected areas on the leaf become mottled with yellow, and upon the surface pustules appear (fig. 61, a.). These are cup-shaped conceptacles produced by the causal fungus, and in which the spores are borne. The spore pustules consist of a firm, dark colored exterior wall, enclosing a more delicate inner covering which contains a mass of thread-like filaments on which the spores are produced (fig. 61, b.). The spore pustules become very numerous and the affected foliage slowly shrivels.

Control. All diseased material should be destroyed by fire. Some florists recommend spraying or sponging the leaves with potassium permanganate.

Anthracnose

Caused by *Colletotrichum kentiæ* Hals.

This disease has been first studied by Halsted* as it was found by him to attack the various ornamental Kentias.

Symptoms. The disease appears as watery spots, which soon become dry (fig. 61, h) and within which are formed the salmon-colored acervuli which contain numerous setæ. In time the dead tissue falls out, leaving holes in which remain the hard, woody vessels which run across. This disease also attacks young seedlings and cripples them beyond any commercial value. The following Kentias are subject to the attacks of the anthracnose: Kentia belmoreana, K. canterburyana, and K. fosteriana.

Control. It is difficult to keep this disease in check unless the infected material is removed and destroyed by fire. Spraying the plants weekly with a standard fungicide will keep the anthracnose in check.

Exosporium Leaf Spot

Caused by *Exosporium palmivorum* Sacc.

Symptoms. The disease is characterized by mi-

* Halsted, B. D., New Jersey Agr. Expt. St., Fourteenth Ann. Rept.: 407-409, 1893.

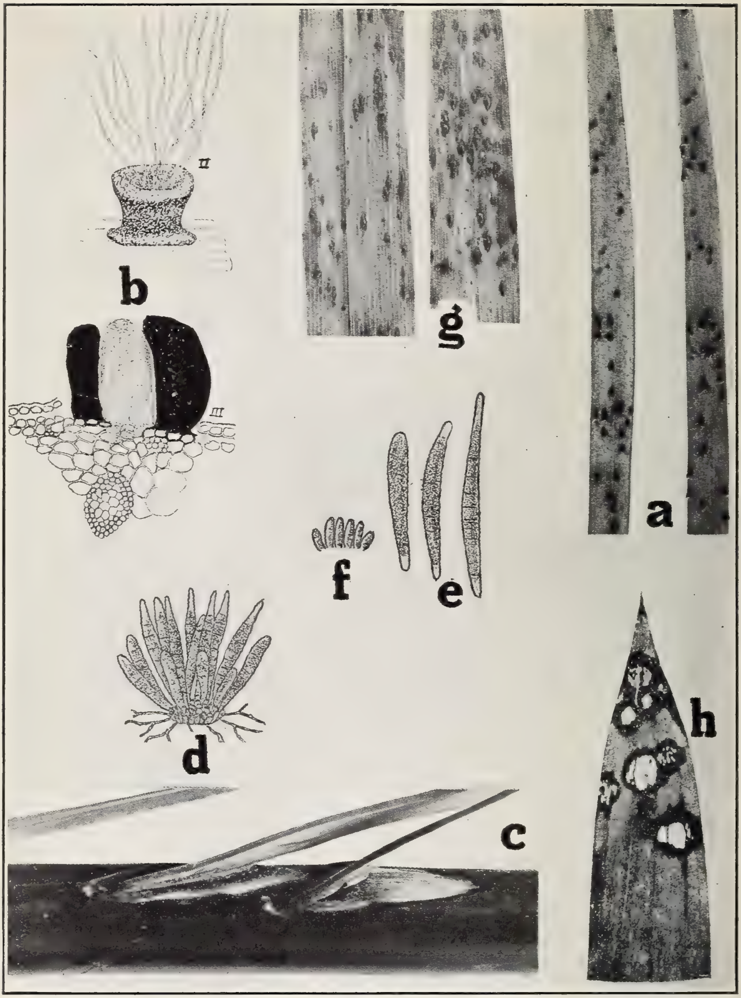

FIG. 61. PALM DISEASES.

a. Palm smut, *b*. Palm smut fungus (after Stone and Smith), *c*. Exosporium leaf spot, *d*. cluster of spores of *Exosporium palmivorum*, *e*. individual spores of *E. palmivorum*, *f*. conidiophores of *E. palmivorum* (*d-e* after Trelease), *g*. Sphærodothis leaf spot (after Smith, R. E.), *h*. anthracnose (after Halsted).

nute brown spots. These are often so numerous as to involve the entire leaf, causing it to dry up and die (fig. 61, c.). This trouble is very common on greenhouse palms, especially on those which are kept in too long under shade. It is common on Phœnix canariensis, on P. tenius and on P. reclinata. The disease undoubtedly must have been introduced from Europe with imported stock. Trelease* observed it in America in 1897.

The Organism. The sporodochia are superficial black, and dense (fig. 61, d), visible to the naked eye as a black mold. The spores are borne singly, are olive brown in color, and are many times septate (fig. 61, e and f.).

Control. The disease seldom occurs in well lighted and well ventilated greenhouses. Where the disease makes its appearance, more attention should be given to the ventilation, and the shading should be gradually diminished. All infected material should be cut off and destroyed by fire; the plants should be sprayed with a standard fungicide.

Leaf Blight

Caused by *Pestalozzia palmarum* Cke.

Symptoms. This disease appears as transparent, dirty white spots at the tip of the leaflets or at the axils. The spots spread quickly and it is not uncommon to find numerous leaves killed, and the affected plant thereby badly disfigured. As the

* Trelease, W., Rept. Mo. Bot. Gard. 9: 159, 1898.

affected tissue dries, the spore masses are formed on the upper part of the leaflets and appear as a black exudate.

Control. Infected material should be cut out and destroyed by fire. Infected plants should not be syringed, for in this way the spores of the causal organism are spread wholesale. Spraying with a standard fungicide is also recommended.

Leaf Spot

Caused by *Sphærodithis neo washingtoniæ.*

The disease is mentioned by Smith* as occurring in California. The leaves become covered with small elongated, black, slightly elevated spots (fig. 61, g.). Affected leaves should be removed and burned, and the plants sprayed with a standard fungicide.

Pansy (*Viola tricolor*).

Cultural Considerations. Pansies are grown mostly out of doors. Occasionally, however, florists raise them indoors as pot plants for purposes of window decoration. Its cultural requirements are about the same as for the violet (see p. 351).

Diseases of the Pansy

Pansies, like violets, are subject to about the same diseases.

* Smith, R. E., and Smith, E. H., California Agr. Expt. Sta., Bul. 218: 1148, 1911.

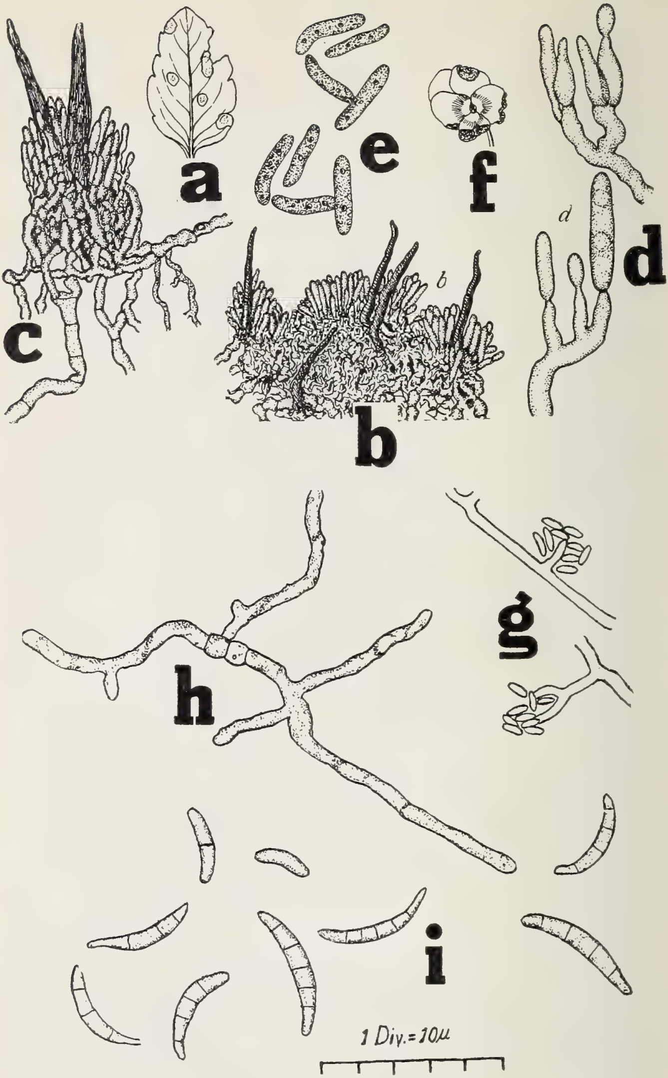

FIG. 62. PANSY DISEASES.

a to *f*. *Colletrotrichum violæ-tricoloris* R. E. Smith, *a*. affected leaflet, *b*. several confluent acervuli with mycelium, setæ, and conidia, *c*. single acervulus, more enlarged, *d*. basidia and production of conidia, *e*. conidia, *f*. affected blossoms, *g* to *i*. *Fusarium violæ*, Wolf, *g*. formation of microconidia, *h*. germination of macroconidia, *i*. macroconidia (*a-f* after Smith, R. E.; *g* to *i* after Wolf, F. A.).

Anthracnose

Caused by *Colletotrichum violæ-tricoloris* R. E. Sm.

Symptoms. The disease attacks the petals, and affected flowers become deformed, and fail to produce seed. This is a serious consideration especially from the seedman's point of view. The spots on the leaves (fig. 62, a) are small with prominent margins.

The Organism. The acervuli are numerous, the stroma poorly developed, and the setæ mostly single or in pairs, short, two septate and deep brown in color. The conidiophores are short, the conidia oblong or slightly curved, with blunt ends (fig. 62, b-f.).

Control. The disease is usually introduced with the seed. All shriveled seed should therefore be discarded, and the healthy ones soaked for five minutes in a solution made of one ounce of formaldehyde in twenty gallons of water. Diseased plants should be destroyed by fire. Pansy beds where anthracnose is present should be kept on the dry side of the house. The plants should not be sprinkled with water, as in this way the spores of the causal fungus may be spread about. Healthy plants may be protected by spraying with a standard fungicide.

Leaf Spot

Caused by *Cercospora violæ* Sacc.

Symptoms. This disease appears as small dead

spots surrounded by a definite black border. The spots soon enlarge and when very numerous cause the premature death of the foliage. The trouble is also met with on the blossoms; the petals in this case become spotted and blotched. Affected young blossoms become distorted or fail to open altogether.

The Organism. The conidiophores of the fungus are short, simple and grayish. The conidia are long, slender, rod shaped, hyaline, and many septate.

Control. It is claimed by Stone and Smith* that good results were obtained by spraying with Bordeaux. The latter, however, is objectionable because of its staining the blossoms. Ammoniacal copper carbonate may therefore be used instead. Spraying may be done at intervals of every two weeks. All dead and infected material should be destroyed by fire.

Root Rot

Caused by *Fusarium violæ* Wolf.

This disease causes a rot of the roots and stems. The causal organism (fig. 62, g to i) is usually brought in the house with infected compost. As a control measure soil sterilization is recommended (see pp. 32-43).

* Stone, G. E., and Smith, R. E., Mass. (Hatch) Agr. Expt. Sta. Ann. Rept. 11: 152, 1898.

Crown Rot

Caused by *Rhizoctonia solani* Kuhn.

Crown rot first appears in the form of minute lesions at the crown of the plant. These enlarge and penetrate the tissue deeply until the plant is practically girdled. Rotting usually sets in, whereupon the prostrate branches, the leaves, and petioles also rot. For a description of the causal organism and for methods of control, see p. 20.

Pandanus or Screw Pine (*Pandanus veitchii*)

Cutural Considerations. Screw pines are forced extensively and are used as ornamental house plants. They require a temperature of 65 to 70 degrees F. and must be exposed to full light, especially in the winter. The plant flourishes best in a soil composed of two parts of heavy loam and one part of thoroughly rotted cow manure. The soil required is a heavy loam to which is well worked in one-third of thoroughly rotted cow manure.

Diseases of the Pandanus. Pandanus is considered a very healthy plant. There are, however, two fungi that proved injurious; these are *Nectria pandani* Tul. and *Melanconium pandani* Lev., which are known to be parasites.

Poinsettia (*Euphorbia pulcherima*)

Cultural Considerations. Poinsettias are extensively grown for the Christmas trade. The plants

prefer a soil consisting of fibrous loam, one-fourth of which is well rotted cow manure. Poinsettias require frequent repotting to prevent them from becoming potbound. The night temperature should never go down below 55 degrees F. As the plants advance in age, the temperature is raised to 65 or 70 degrees. A few days before Christmas the stock should be ready and the temperature lowered to 50 degrees F. Great care should be exercised to prevent the potted plants from becoming either overwatered or too dry. Poinsettias that are to be used for cut flowers should have the stem end dipped in hot water for a few moments and then placed in cold water. This procedure will cauterize the wounds and thus will add to the keeping qualities of the blossoms.

Diseases of Poinsettias

Poinsettias seem to be remarkably free from diseases. This is especially true as the plants outgrow the cutting stage.

Collar Rot

Caused by *Rhizoctonia solani* Kuhn.

Symptoms. The trouble is confined mostly to cuttings that have been planted in an infected soil. The lesions unite and in nearly every case form a collar around the stem on the surface of the soil. The collar formed is narrow, depressed, and dark in color. For a description of the causal organism and methods of control, see p. 20.

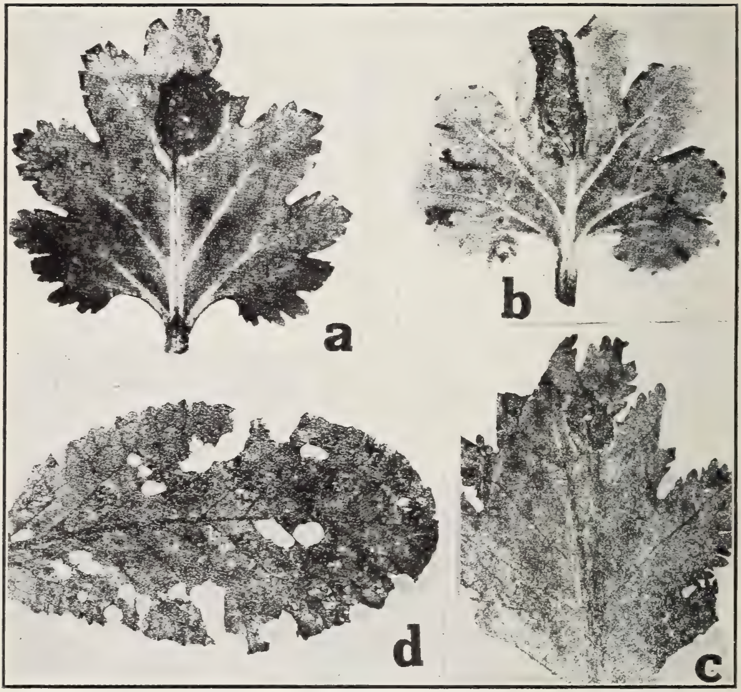

FIG. 63. PRIMROSE DISEASES.

a. Botrytis rot, *b.* Phyllosticta leaf spot, *c.* anthracnose, *d.* Ramularia leaf spot (*a* to *d* after Halsted).

CHAPTER 25

PRIMROSE (*Primula sinensis*)

Cultural Considerations. Young seedlings are greatly injured if the compost contains unrotted manure. When the plants begin to grow rapidly a little bone meal may be worked into the soil. During the blossoming period a little weak liquid manure may be given, but only when the leaves are pale. In transplanting, the crown of the plant should not be planted too deeply in the soil lest it rot. Neither should it be planted too high lest it fall over. After transplanting primroses need shade. Later, however, they should be given the benefit of full light and ventilation. The soil should never be allowed to become dry.

Diseases of the Primrose

Primroses are subject to several serious diseases.

Spot Decay

Caused by *Sclerotinia fuckeliana* (De By.) Fckl.

Symptoms. The conidial stage, *Botrytis vulgaris*, of this fungus causes a spot decay on the foliage (fig. 63, a.). The fungus often thrives on old

and faded blossoms. These, therefore, act as a source of infection. It is needless to add that cleanliness will form a part of the control method. Spraying with any of the standard fungicides is also recommended.

Anthracnose

Caused by *Colletotrichum primulæ* Hals.

Symptoms. Affected leaves become brown and spotted. The spots are more visible on the lower part of the foliage (fig. 63, c.). The acervuli with its black setæ of the causal organism are especially conspicuous when looked at with a magnifying lens. At present little is known of the organism. The disease may be kept in check by spraying with a standard fungicide.

Blight

Caused by *Phyllosticta primulicola* Desm.

Symptoms. On the leaves of the plant appear somewhat circular spots (fig. 63, b) that are brown or whitish in color with a light border, with which are found numerous pycnidia. The disease attacks various species of the genus Primula with different effects. On P. sieboldii and on P. obconia, the trouble is usually confined to the lower leaves. On P. sinensis the central part of the leaf is attacked before the surrounding tissue loses its color. On P. sieboldii the leaves may often be blotched throughout, while on P. obconia one-half of the leaf is

often destroyed before the other half shows any marked deterioration.

Little is known of the causal organism. The destruction by fire of diseased material and spraying with a standard fungicide is recommended.

Leaf Spot

Caused by *Ascochyta primulæ* Wail.

Symptoms. The presence of the disease is shown by oval spots, which spread and often involve the entire leaf. This disease may often be mistaken for the spotting caused by *Phyllosticta primulicola.* However, a microscopical examination will distinguish the two organisms.

Leaf Blotch

Caused by *Ramularia primulæ* Thun.

Symptoms. The presence of the disease is shown by large yellow blotches in the ashen colored centers of which are borne the spores (fig. 63, d.).

The Organism. The conidiophores grow on both sides of the spots, and are rarely branched, continuous and somewhat denticulate. The conidia are thick but taper towards both ends. Their structure is continuous or one septate.

Control. This disease may be kept in check by spraying the plants with a standard fungicide. Infected material should be destroyed by fire.

Roses (*Rosa gallica chinensis*).

Cultural Considerations. As soon as the cuttings form roots which are about one-half inch in length, they should be potted. At this stage, if left too long in the propagating bench, the wood tissue of the cutting will harden and the subsequent health of the plant will be endangered. A medium water-holding capacity is an indication of a good potting soil for roses. Most greenhouse (fig. 64) varieties prefer a heavy loam. Other varieties such as the Maryland thrive best in a soil which contains a large percentage of sand. Roses are very sensitive and readily become injured when given partly decayed organic matter. The case, however, is different when well rotted manure is used, for this latter food exerts a wholesome stimulating effect. The development of a good root system largely depends on the soil texture and on the plant food which it contains. It is necessary to stir frequently the surface soil of rose benches. This not only destroys weeds, but also provides aëration. However, as soon as the surface soil becomes filled with feeding rootlets of the rose plants, the cultivating should be done very superficially or should cease altogether. During active growth, the plants require an abundance of ventilation and a comparatively low temperature.

Diseases of the Rose

Greenhouse roses are subject to the attacks of several important diseases.

Fig. 64. Rose House.

The Bronzing of Leaves

Cause, Physiological.

Symptoms. This trouble commonly affects grafted varieties of the Tea, Bride, and Bridesmaid. By some growers the disease is often mistaken for a stage of the black spot caused by *Diplocarpon rosæ.* Bronzing produces a mottled bronze coloring of the foliage. Later the mottling becomes more prominent in the form of spots, while the adjoining tissue turns pale yellow. Frequently the entire leaflet becomes bronzed with no yellowish color apparent. At times the affected leaflets and leaf stalks drop to the ground. The cells of the affected tissue contain an abundance of calcium oxalate crystals, a condition that indicates poor nutrition. Bronzing is usually confined to two places. First, where a stem has been cut and a new branch has started the leaf at the base begins to bronze; second, where an eye or an auxiliary bud has been rubbed off, the leaf generally becomes bronzed. From studies made at the Massachusetts Station* there seems to exist a difference in susceptibility between young and old plants. Bronzing may be expected to occur on young plants. It is also prevalent both on plants which are forced too rapidly and on weak stock. The selection of strong, hardy stocks and care in feeding will prevent the trouble from becoming serious.

* Massachusetts Agr. Expt. Sta. (Hatch) Ann. Rept.: 156-159, 1899.

Blossom Blight

Cause, unknown.

Symptoms. The trouble manifests itself in the failure of the buds to open. At first the buds seem to develop normally. Soon, however, the outer petals wrinkle, turn yellow or straw colored, and stop growing. Occasionally the buds open partially, but fail to attain normal size. The true cause of the disease is unknown, although, as believed by Stevens and Hall,* it may be due to some physiological disorder in the metabolism of the plant. No control method is known.

Crown Gall

Caused by *Pseudomonas tumefaciens* Sm. and Towns.

This disease is a very dangerous enemy to outdoor roses. It has, however, proved of little economic importance to indoor roses (fig. 65, b.). For a description of the symptoms and of the organism, see p. 115.

Downy Mildew

Caused by *Peronospora sparsa* Berk.

Symptoms. Downy mildew is more difficult to detect than the powdery mildew. It is also more

* Stevens, F. L., and Hall, J. G., North Carolina Agr. Expt. Sta., Thirty-first Ann. Rept.: 78-79, 1908.

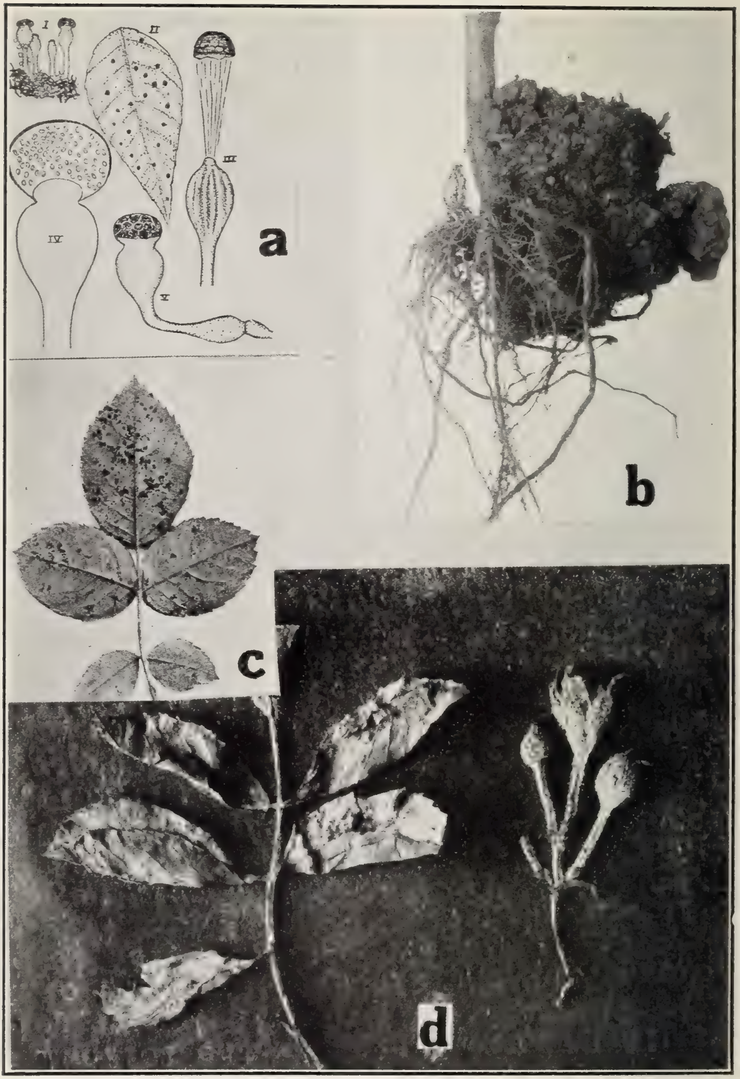

FIG. 65. ROSE DISEASES.

a. Pilobolus crystallinis (1) Group of sporophores, (2) specks on leaf, (3) method in which the spore bearing cap is blown off, (4) spore head magnified, (5) young sporophore (after Clinton), *b.* crown gall, *c. Phragmidium subcorticum* (after Smith, R. E.), *d.* powdery mildew.

difficult to control, because the causal organism lives within the tissue of its hosts. This mildew resembles that of the grape, potato, bean, etc. It usually appears in irregular spots. On the lower surface of the leaves, the fruiting of the fungus resembles a downy white to purple coating. It is fortunate that this disease is uncommon in the United States, and even more so under greenhouse conditions.

The Organism. The conidiophores are nine times branched; the branchlets are reflexed. The conidia are pale gray, subelliptic in form.

Control. The removal and burning of infected material and the spraying of the plants with a standard fungicide will keep it in check.

Mechanical Spotting

Caused by *Pilobolus crystallinus* (Wigg.) Tode.

Symptoms. The trouble, if such it may be called, is a small specking resembling fly speck on the leaves and flowers. There is but one case on record reported by Clinton.* It appeared on two benches in a rose house. The infected benches were heavily mulched with cow manure, while the others did not receive this treatment. A careful inquiry revealed the fact that on the two manured beds the fungus *Pilobolus crystallinus* was very abundant. The

* Clinton, G. P., Conn. Agr. Expt. Sta., 38th Ann. Rept.: 24-25, 1914.

spore heads of this organism (fig. 65, a) when ripe are shot off into the air and stick to any object on which they may alight, which in this case happened to be the foliage and blossoms of the roses. The mechanical spotting here referred to was caused by nothing more than the presence of the spore heads of the fungus. The trouble ceased when the fungus no longer produced spores. The specking on the rose blossoms was not serious enough to injure their market value.

Rose Rusts

Caused by Phragmidium species.

Rose rusts are more commonly found on plants growing in the open. These, however, may be introduced indoors with cuttings, or plants first started in the nursery.

Phragmidium subcorticum (Schrank) Wint. This fungus causes the true rust of roses. It is very prevalent in Europe, is of little importance in the United States. On the leaves this rust appears in small circular spots (fig. 65, c), and on the stems and petioles in large powdery masses. At first the sori or spore clusters are orange-yellow, but later turn brick red.

Phragmidium speciosum Fr. This fungus is the cause of a rose rust which affects the stems and which rarely appears on any other part of the plant. The sori are black and irregularly scattered. The causal fungus is carried over from year to year as viable mycelium in the affected host. Cutting out

or burning the diseased stems will prevent the further spread of the disease.

Other Rose Rusts. There are other species of Phragmidiums which have been found by Mikio Kasai.* Among them are the following: *Phragmidium americanum* (Pk.) Diet. found on Rosa dahierica; *Phragmidium fusiforme* Schroet on Rosa acicularis; *Phragmidium Japonicum* Diet. on Rosa multiflora, R. wichuriana, R. luciæ; *Phragmidium rosæ multifloræ* Diet. on Rosa multiflora, R. lævigata; *Phragmidium rosæ rugosæ* Kasai, on Rosa rigosa; *Phragmidium yezoense* Kasai on Rosa rugosa.

Powdery Mildew

Caused by *Sphærotheca pannosa* Wallr.

Symptoms. Powdery mildew is a very troublesome disease of greenhouse roses. The disease appears as powdery, whitish patches on the leaves, stems, and blooms. The affected foliage fails to develop normally, becoming uneven and twisted, curled and reddened (fig. 65, d.).

The Organism. On the rose the conidial or oidium stage is most frequent. The conidia are ovid, hyaline, and are borne on short conidiophores. The same fungus also causes the powdery mildew of the peach, in which case the ascus stage is most common.

Control. It is believed by many florists that

* Mikio Kasai, Trans. Sapporo Nat. Hist. Soc. 3: 27-51, 1909-1910.

drafts favor mildew. These statements seem to be borne out by actual observations. Mildew often starts first on rose plants facing broken panes. From these, the spores are then carried by the draft to other plants until the disease becomes thoroughly established in the house. It is, therefore, imperative that attention be directed to broken glass. While an abundance of ventilation is necessary, drafts of all sorts should be avoided.

Mildew may also be kept in check by boiling sulphur in the greenhouse for two to three hours, twice a week. The house is closed tightly during the operation, and ordinary flowers of sulphur is placed in a kettle over a small kerosene flame, as otherwise a big flame may cause the sulphur to catch fire. Mildew may also be controlled by spraying with potassium sulphide, at the rate of one ounce of the chemical dissolved in two gallons of water. The spray is only effective when used fresh. The chemical should be kept in a tightly closed bottle.

Black Spot

Caused by *Diplocarpon rosæ* Wolf.

Symptoms. Black spot is often very troublesome on greenhouse roses. Attacked plants lose their foliage and the general effect is a weakening of the plant and the formation of stunted blossoms. The spots are more or less circular, black, with a characteristic fringed border (fig. 66, a.). Frequently the leaf tissue adjacent to the spots becomes pale or

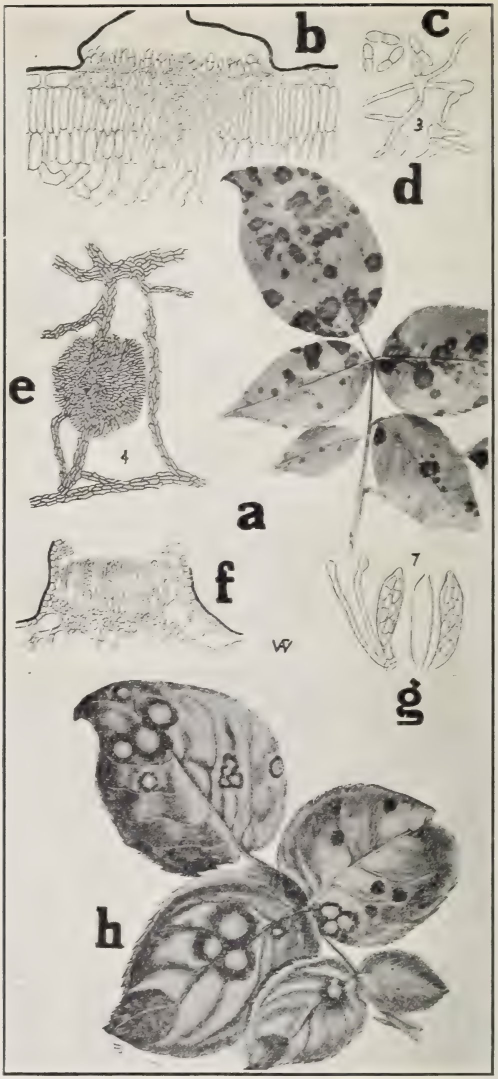

FIG. 66. ROSE DISEASES.

a. Black spot on foliage, *b-g.* various stages of *Diplocarpon rosæ* (after Wolf), *h. Septoria rosæ* (after New Zealand Ann. Rept., 1915).

chlorotic, long before the affected leaves drop off. As the spots become old, minute specks appear within. These are the fruiting bodies of the causal organism.

The Organism. The fungus of black spot has two spore stages. The summer stage (fig. 66, b) is known as *Actinonema rosæ* (Lib.) Fr. The pycnidia are tuberculoid in shape, scattered, black. The conidia (fig. 66, c) are oblong, constricted, and are borne on short conidiophores. The ascus or winter stage (fig. 66, f and g) was discovered by Wolf,* who named it *Diplocarpon rosæ* Wolf. The winter stage matures on dead and fallen leaves which have wintered over. The mature asci are oblong. The ascospores are discharged from an apical pore and pile up in whitish masses in the opened perithecia. The ascospores are not so strongly constricted at the septum as is the case with the conidia or summer spores, both of which are hyaline in color.

Control. There seems to be a difference in the susceptibility of some varieties to the disease. It seems that the bushy sorts are more susceptible than the climbing varieties. The thin-leaved varieties, too, seem to possess less resistance than those with thick leaves.

Spraying is often recommended for the control of black spot. The more recent investigations by Massey † show that ammoniacal copper carbonate is not as efficient as Bordeaux mixture for the con-

* Wolf, F. A., Science N. S. 35: 151, 1912.
† Massey, L. M., The American Rose Mann: 67-71, 1918.

trol of the disease. Furthermore, the disease may be kept in check by dusting with sulphur-arsenate made of a mixture of ninety parts finely ground sulphur and ten parts powdered arsenate of lead. A lime sulphur solution composed of one part of the commercial concentrate solution to fifty parts of water is as efficient in controlling black leaf spot as is Bordeaux or sulphur-lead-dust. It is purely for the florist to decide whether he wishes to spray or to dust. The sulphur-arsenate may be applied with an efficient little machine known as the Corona hand duster. The same material is also very efficient for controlling the powdery mildew of the rose. In this case, too, the work of Massey has shown that sulphur-arsenate is even more efficient than lime-sulphur solution 1-50, or Bordeaux mixture 5-5-50.

Anthracnose

Caused by *Glœosporium rosæ* Hals.

Symptoms. The chief feature of this disease as observed by Halsted * is a premature dropping of the foliage. Some stems may be entirely bare while others may have a few leaves still clinging to them. Infection may start on the leaves first, in which case they drop off, and soon develop the salmon-colored pustules on the dead spots. Generally, however, the trouble starts at the tender branches and works its way downwards. If infection takes place at a

* Halsted, B. D., New Jersey Agr. Expt. Sta., Fourteenth Rept.: 401-409, 1893.

lower portion of the cane it will soon work its way up. The characteristic salmon-colored pustules are usually found in abundance on the affected canes. The rose anthracnose is very similar to that of the raspberry, although the latter is induced by a different species of fungus. Very little is known of the causal organism of the rose anthracnose.

Control. All dead leaves and canes should be removed and destroyed by fire. Spraying with a standard fungicide is also recommended.

Leaf Spot

Caused by *Mycosphærella rosignea* (E. and E.) Lind.

Symptoms. Purplish blotches appear on the leaves and later develop into sharply defined spots with brown centers and purplish borders. The perithecia of the fungus are found in large numbers on the dead tissue. It seems that the one-year-old plants are more susceptible to the disease than the two-year-old plants of the same variety. The disease usually occurs in the winter, but seldom causes serious damage.

The Organism. The perithecia are black and partly erumpent, while the asci are rather oblong and are arranged in two series in the ascus.

Control. The destruction by fire of all diseased material, and spraying with a standard fungicide is recommended.

Septoria Leaf Spot

Caused by *Septoria rosæ* Desm.

Symptoms. This disease is characterized by distinct spots on the foliage (fig. 66, h.). Spots with centers of creamy or dirty white surrounded by broad purple margins appear on the foliage. The pycnidia are formed in the center of the spots. Little is known of the nature of the causal organism. The destruction of all infected material by fire and spraying with a standard fungicide will keep the disease in check.

Stem Canker

Caused by *Coniothyrium fuckelii* Sacc.

Symptoms. This disease usually produces cankers of the canes and branches. The lesions are brown in the center with a black border, limited by an outward reddish band or zone. The same disease attacks apples and raspberries.

The Organism. It has long been suspected that Leptosphæria was the ascus stage of *Coniothyrium fuckelii.* This Stewart * seems to have verified, although definite evidences are still lacking. The perithecia are in groups, globose, black with fringed mouths. The asci are cylindric, eight-spored, one-rowed, three-septate. The pycnidia are similar to the perithecia; the spores are ovate, continuous, and

* Stewart, F. C., New York (Geneva) Agr. Expt. Sta. Bul. 328: 387, 1910.

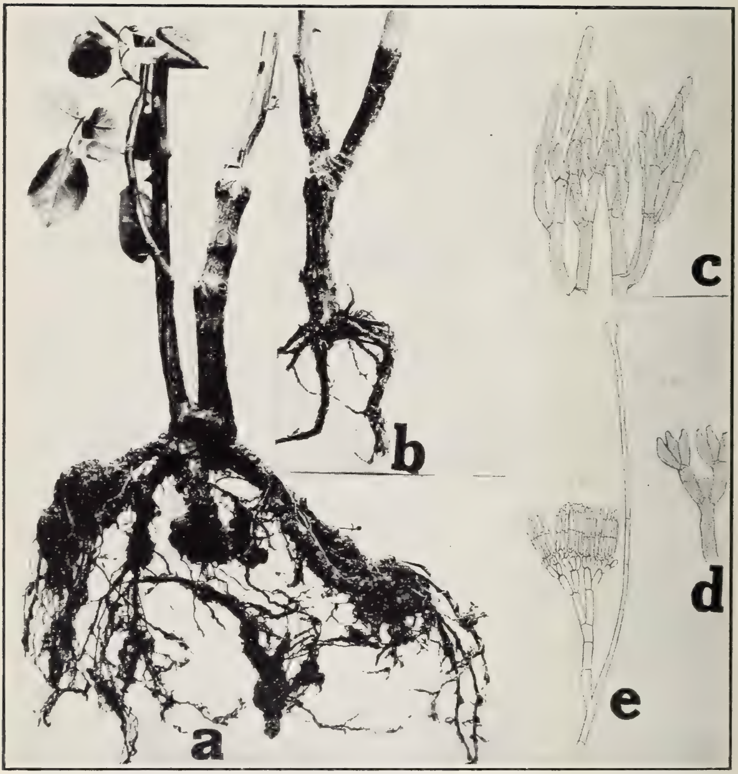

FIG. 67. ROSE DISEASES.

a. Root knot, *b.* Cylindrosporium crown canker, *c-e,* stages of the Cylindrosporium fungus (*b-e* after Massay, L. M.).

grayish. Careful cutting and burning of affected material is suggested.

The Crown Canker

Caused by *Cylindrocladium scoparium* Morgan.

Symptoms. Crown canker is perhaps one of the most important diseases of roses under glass. Although the percentage of roses that are actually killed is rather small the effect of the disease is to increase the financial loss by weakening the plants and reducing the yields in marketable blossoms. The disease first attacks the plants at the crown just above the surface of the soil, producing lesions both on the crown and on the roots. Infection often starts at the place of union of the scion and stock. The trouble is indicated by a slight discoloration of the bark, which soon deepens until the affected tissue becomes black and watersoaked (fig. 67, b.). As the lesions increase in number, the crown of the plant becomes girdled, and cracks appear in the bark of the infected area, which is sunken and in sharp contrast with the healthy bark surrounding it.

Another constant symptom of the disease is the punky consistency of the affected tissue. Although this effect is marked in the crown, especially of the diseased roots, the condition is further noticeable in the bark and sap wood of the affected crown or roots. The diseased roots send up suckers that are weak, spindly, and pale. A close examination will show that these, too, are affected at the point of

attachment to the root. Affected plants linger for a long time, but they produce only a few stunted blossoms.

The Organism. The causal organism produces fertile and sterile hyphæ. The spores are borne in fascicles, are cut off from the short conidiophores by a constriction, and are held together by a sticky substance, but separate quickly when placed in water. The spores are cylindric, one septate, and hyaline (fig. 67, c to e.).

Control. Since the causal organism lives in the soil, steam sterilization is recommended. All dead or infected material should be destroyed by fire. The disease may also be avoided to some extent by placing grafted plants with the graft union above the soil. This will prevent infection at the wounded surface. Attention should also be given to the watering of the plants. Crown rot is worse in overwatered beds.

Cercospora Leaf Spot

Caused by *Cercospora rosicola* Pass.

Symptoms. This disease is characterized by roundish spots, gray in color, with a dark border separating the healthy from the diseased tissue.

The Organism. The conidiophores grow in tufts, are densely gregarious, small and dark colored. Conidia are straight, short, cylindric, and hyaline. Spraying with a standard fungicide is recommended.

FIG. 68. RUBBER PLANT AND SCHIZANTHUS DISEASES.

a. Leptostromella leaf spot, *b*. cross section of rubber leaf to show relationship of the parasite to its host, to the left one magnified spore (after Hatch Expt. Sta. 9th Rept. 1897), *c*. and *d*. acervulus and germinating spores of *Colletrotrichum schizanthi* Jen (after Jensen, C. N.).

The Rubber Plant (*Ficus elastica*)

Cultural Considerations. Rubber plants generally adapt themselves to wide ranges of temperature. They may do as well when exposed to full sunlight as when kept under partial shade. In the summer it is advisable to plunge them out of doors to be hardened. The plants require frequent feedings with liquid manure.

Diseases of Rubber Plants.

The rubber plant is considered very hardy. It is subject to but few diseases of importance.

Leaf Spot of India Rubber

Caused by *Leptostromella elasticæ* Ell. and Ev.

Symptoms. The India rubber (Ficus elastica) is usually considered a hardy plant. Under greenhouse conditions, however, it is often attacked by a leaf spot which at times proves very disastrous. The presence of the disease is first manifested by small spots (fig. 68, a) or streaks. These soon increase in number and in size until the entire leaf area becomes involved, resulting in a premature dropping of the foliage. The spots, which at first appear yellowish, soon turn brownish and finally become gray. The dead tissue is sharply defined from the living as it is banded by a narrow black margin. The pycnidia (fig. 68, b) appear scattered within the

spots. The pycniospores are oblong, hyaline, and one celled.

Control. All dead and infected leaves should be destroyed by fire, and the plants should be sprayed with ammoniacal copper carbonate.

SCHIZANTHUS (*Schizanthus pinnatus*)

Cultural Considerations. Schizanthus is forced mostly as an early spring flower. It does not require a very rich soil, and thrives best under night temperatures of 45 to 50 degrees F.

DISEASES OF SCHIZANTHUS.

Schizanthi are very hardy plants. There is but one disease recorded in the United States on the greenhouse plants.

ANTHRACNOSE

Caused by *Colletotrichum schizanthi* Jen. and Stewart.

Symptoms. Anthracnose has been found by Jensen and Stewart* to be a very destructive disease on greenhouse Schizanthus. The younger parts of the plant are usually more susceptible than the older ones. On infected stems, branches, or petioles, the disease causes watersoaked areas which extend in all directions. The spots become depressed, and grow

*Jensen, C. N., and Stewart, V. B., Phytopath 1: 120, 1911.

deeper and deeper until the affected parts topple over and break. The lesions are light brown and dotted with the acervuli of the fungus. On the older parts of the plant the lesions take on the forms of cankers, although they do not sink as deeply. Occasionally, the disease attacks the leaves, forming light brown spots which are irregularly scattered.

The Organism. In structure *Colletotrichum schizanthi* is not different from any other Colletotrichum. The black setæ are very numerous. The conidia are one celled, hyaline, oblong, and granular (fig. 68, c and d.).

Control. Diseased plants or parts of plants should be destroyed by fire. Spraying with a standard fungicide is also recommended.

CHAPTER 26

THE SWEET PEA (*Lathyrus odoratus L.*)

*Cultural Considerations.** The best position for a sweet pea house (fig. 69, a) is east and west with a full southern exposure. The sides of the house should be considerably higher than for other crops. Sweet peas require an abundance of water during the growing season. Frequent syringing of the foliage is also necessary to keep the red spider in check. In ventilating care should be taken not to admit cold drafts; nor should the plants ever be chilled. Exposure to drafts or sudden falls in temperature will predispose the plants to bud drop and to powdery mildew.

Diseases of the Sweet Pea

Indoor sweet peas are subject to numerous diseases. These, if allowed to spread, will deprive the grower of his year's labor and profits.

Physiological Troubles

These troubles are usually induced by improper conditions of the soil. Root burn, for instance, may

* For fuller information see Taubenhaus, J. J. Culture and Diseases of the Sweet Pea, 1917. E. P. Dutton Co., New York, N. Y.

FIG. 69. SWEET PEA DISEASES.

a. Ranch of sweet pea houses, *b.* sick soil infected with *Sclerotinia libertiana;* notice the wilting and dying of the seedlings, *c.* some of the same soil steam sterilized resulting in a perfect stand, *d.* germinated sclerotia showing fruiting caps of *S. libertiana.*

be induced by the excessive use of wood ashes applied with the manure. It is not uncommon for growers to use wood ashes at the rate of 1,500 lbs. to 4,500 square feet of bed space. This would be equivalent to nearly seven and one-half tons per acre. Under such conditions the roots actually burn up because of the strong alkalinity of the soil. Moreover, hard-wood ashes contain about 30% caustic lime and from 5 to 12% potash. Both of these elements in excess in soil render it too alkaline for plant growth. To remedy this trouble, acid phosphate is used, followed by a good drenching with water. This will help to neutralize the alkalinity and to restore the balanced ration.

Malnutrition

Cause, physiological.

Symptoms. The symptoms of malnutrition of sweet peas are identical with those of greenhouse cucumbers (see p. 134).

Cause. Overfertilization may be mentioned as one of the many causes of malnutrition. An analysis of an overfed soil will readily show that the soluble salts present are in excess of what the plant requires and is able to withstand. Table 17 a by Haskins * clearly shows that with the exception of nitrogen, the soluble salts were in excess of what the

* Haskins, H. D., Mass. Agr. Expt. Sta., Twenty-fifth Ann. Rept.: 76-79, 1913.

TABLE 17 A

Average Composition of an Overfed Soil Compared to a Normal Soil

	Pounds per Acre	
	Normal Soil	*Overfertilized Soil*
Total water soluble salts	12.874	15.193
Soluble nitrogen	209	91
Soluble potash	2.433	2.957
Soluble phosphoric acid	traces	traces
Soluble calcium oxide (lime)	580	657
Soluble magnesium oxide	369	435
Soluble sodium oxide	972	1.923

plant could stand. It further indicates that a large amount of horse manure was used in this particular case.

Control. It seems that the average greenhouse beds are faulty in construction. One of the main requisites is to provide good drainage. This is far more important in the greenhouse than in the open. Crops need plant food. A slight excess is desirable to force quick growth. An overdose of horse manure or chemical fertilizers will produce more harm than good. No guesswork should be permitted to take the place of accurate calculation in applying fertilizers. The surface area of the greenhouse bed may be easily expressed in terms of acreage. Suppose that 500 pounds of sulphate of potash is required per acre (4,800 square yards), then in the greenhouse 1.6 ounces would be required per square yard. In this way, all fertilizers may be applied

accurately. In relying on guesswork the general results are likely to be the application of an overdose of fertilizers or manure.

In order to gain an approximate idea of the total amount of plant food as well as the available plant food furnished by horse manure when mixed with the soil for greenhouse use, Haskins has prepared the following data:

	Pounds of Total Plant Food per Acre			*Pounds of Plant Food Likely to be Available the First Season*		
	A*	B*	C*	A*	B*	C*
Nitrogen......	5.800	3.863	2.900	2.320	1.545	1.160
Phosphoric acid	2.800	1.850	1.400	2.380	1.585	1.190
Potash........	5.300	3.530	2.650	3.971	2.648	1.985

* "A" represents one-half manure, one-half soil; "B", one-third manure and two-thirds soil; "C", one-fourth manure and three-fourths soil.

In greenhouses when the ill effects of overfertilization become apparent, the soil should be leached out with hot water as soon as the crop is removed. This may also be done with lukewarm water, while the crop is still growing. In either case good drainage should always be provided in order to carry off the salts in solution. Where conditions for leaching are not favorable as may be the case with a cucumber crop, about 3 inches of fresh loam should be applied to the surface of the bed and thoroughly worked in.

Bud Drop

As the name implies, the young flower buds at a very early age turn yellow and drop off. This drop should not be confused with the drop produced by the anthracnose disease. In the latter case, the flower develops into a normal spike but it is attacked soon by the fungus *Glomerella rufomaculans* which girdles it at the point of attachment between the flower and the peduncle. Here the flower often drops off, leaving behind the beheaded peduncle. In the former case, however, the minute young flower bud never develops, instead it turns yellow and drops off. There seems no doubt that the drop is a physiological disease and is induced by an unbalanced condition of the food elements in the soil. This may occur in a soil that has been excessively fed or in a soil that is lacking in plant food.

Bud drop may be readily remedied by the application to the soil of small quantities of muriate of potash and acid phosphate.

Mosaic, see p. 102.

Streak

Caused by *Bacillus lathyri* Manns and Taub.

Streak is a very serious disease of outdoor sweet peas. Fortunately it is not known to attack greenhouse sweet peas.

Symptoms. Although not occurring indoors, the

symptoms of streak are here given to enable the grower to know the disease should it ever appear in the greenhouse. Like the Bacteriosis of beans, streak makes its appearance in wet houses. On the sweet pea the disease usually appears just as the plants begin to blossom. It is manifested by light reddish-brown to dark brown spots and streaks (the older almost purple) along the stems, having their origin usually near the ground, indicating the fact that the distribution of the disease is by the spattering of water droplets and soil particles, and that infection takes place through the stomata. The disease becomes quickly distributed over the more mature stems until the cambium and deeper tissues are destroyed in continuous areas, whereupon the plant dies. Occasionally petioles and leaves show infection; the latter exhibiting the usual water-soaked spots and resembling the bacterial leaf blight of beans.

The disease is not a vascular infection; it confines its attacks to the mesophyll, the cambium and deeper parenchymatous tissues. The lesions of the stems gradually enlarge and deepen until they come together.

Downy Mildew

Caused by *Peronospora trifoliorum* De By.

Symptoms. This trouble usually makes its appearance when the plants are a few inches high or it may attack older plants. Affected leaflets become

sickly yellow, finally white, shrivel and die, showing but very little of the fruitings of the causal organism on the surfaces of the affected areas. Under very moist conditions, however, the spots become covered with a delicate grayish lilac colored moldy growth. The latter consists of the summer spores of the fungus. The winter or resting spores are found imbedded in the dead tissue of the host. Massee * claims that downy mildew is a serious disease of outdoor sweet peas in England. Although the fungus *Peronospora trifoliorum* is very common on other legumes in the United States, it has not yet made its appearance on the sweet pea. Mr. Massee says that *Peronospora viciæ* Berk. also attacks sweet peas in England.

Stem or Collar Rot

Caused by *Sclerotinia libertiana* Fckl.

Symptoms. This is usually a seedling disease, although it may attack plants of all ages. Like the Rhizoctonia rot, it attacks many different kinds of seedlings. The trouble is most severe in poorly ventilated houses in beds overwatered or lacking proper drainage, and in damp places out of doors. The disease spreads very quickly and is soon fatal. Affected plants first show a wilting of the tip and a flagging of the leaves, and then the seedlings fall over and collapse (fig. 69, b.). The causal fungus does not seem to attack the roots, but penetrates the collar of the stem and completely invades the

* Massee, G., Sweet Pea Annual: 20-21, 1906, London

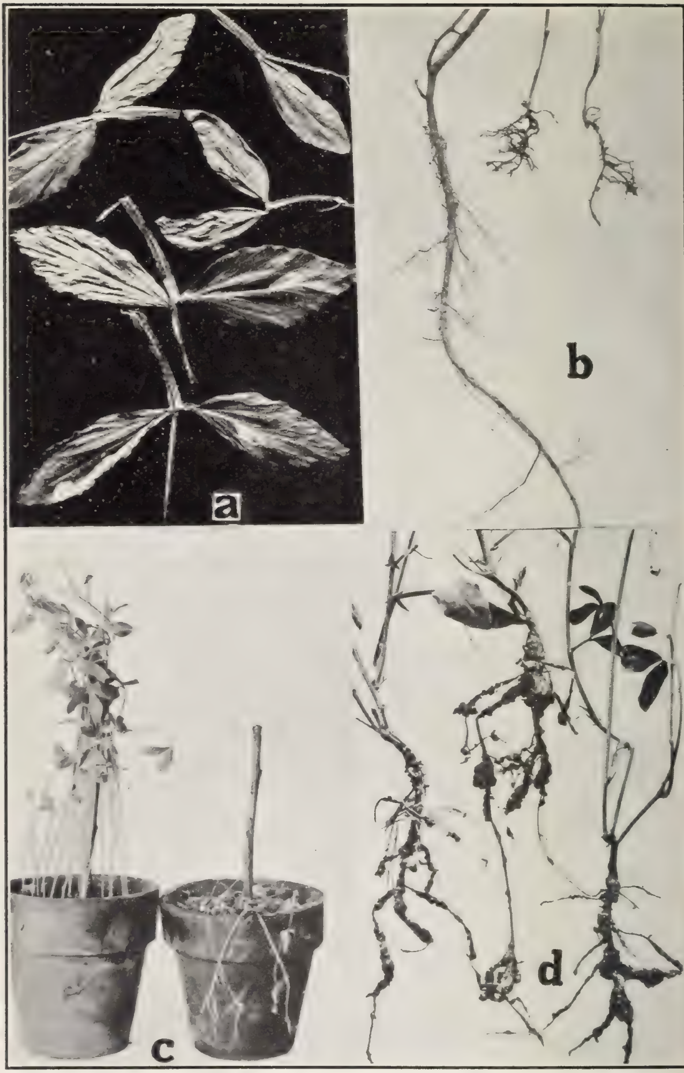

FIG. 70. SWEET PEA DISEASES.

a. Anthracnose, *b*. Thielavia root rot, to the right two diseased roots, to the left one healthy root, *c*. Fusarium rot, germination of seed in diseased and steam sterilized soil compared, *d*. root knot.

vessels, thus clogging the upward flow of the water from the roots to the stem. Freshly collapsed plants usually have a water-soaked appearance, and are later overrun by a white weft, which is merely the mycelium of the fungus; this is followed by sclerotia (fig. 69, d) (resting bodies), which are found scattered here and there on or within the affected stems. The fungus is a soil organism which occasionally causes trouble in clover fields. It is introduced with animal manure. For a description of the causal organism and methods of control, see p. 151.

Thielavia Root Rot

Caused by *Thielavia basicola* Zopf.

Symptoms. Plants severely infected with Thielavia develop practically little or no root system, since the new roots are destroyed as soon as they are formed. Generally all that is left is a stub, which is charred in appearance (fig. 70, b.). The disease often works up from the affected roots to the stems, some 2 or 3 inches above ground. Affected plants neither die nor wilt, but remain dwarfed, stunted, and sickly pale in color, and produce few or no blossoms. For a description of the causal organism and methods of control, see p. 355.

Powdery Mildew

Caused by *Microsphera alni* (Waller) Salm.

Symptoms. Powdery mildew is a very common trouble of greenhouse sweet peas. The causal fun-

gus grows on the surface of the leaves in powdery white patches. Affected leaves become pale and drop off prematurely. The ascus stage of *Microsphera almi* is rarely found on the freshly affected foliage. It is, however, fairly abundant on the dead and fallen leaves on the ground. The mildew may be controlled in the same manner as for the rose (see p. 323).

Spot Disease

Caused by *Mycosphærella pinodes* (Berk. and Blox.) Niesel.

Symptoms. Although it is a dangerous enemy of the garden pea, this disease has not attacked sweet peas very often, especially where they are grown under greenhouse conditions. The pycnidial stage of the fungus is found on foliage of the garden pea and of the sweet pea. The winter stage may be found on dead leaves and vines of the sweet pea and of the garden pea.

The Organism. The pycnidia are brown, erumpent, globose, with thin walls. The spores are hyaline, cylindrical, one septate and rounded at both ends; they are guttulate only when young. The perithecial stage was discovered by Stone. The brown perithecia are found under the epidermis or deeply sunken in the tissue of the spot. Their mouths are elongated and beaklike. The asci are cylindrical, while the ascospores are elliptical to ovate. Both are two-celled hyaline bodies. Spraying with a standard fungicide may keep the disease in check.

Anthracnose

Caused by *Glomerella rufomaculans* (B.) V. Sch. and Sp.

Symptoms. Like streak, anthracnose has not yet made its appearance on greenhouse sweet peas. Whether this is merely accidental, or whether indoor conditions are unfavorable to the disease remains to be discovered. It is necessary, however, that the grower be familiar with the disease in order to prevent its spread indoors. The symptoms of Anthracnose are manifested in a wilting or dying of the tips, which become whitish and brittle and readily break off. At other times the wilt works downwards and involves the entire branch. Frequently, also, leaves thus infected become brittle and soon drop (fig. 70, a.). Examination of an infected leaf with a hand lens shows that it is peppered with minute salmon-colored pustules. At the time of blossoming the fungus makes its attack on the peduncle, or the fungus attacks both the flower bud and the peduncle, in which case both dry up, although they do not fall off. The most distinguishable symptoms of this disease are on the seed pods. Infected pods lose their green color, become shriveled, and are soon covered with salmon-colored patches, which cannot fail to attract attention.

Organism. The cause of the anthracnose is the fungus *Glomerella rufomaculans.* This fungus causes also the bitter rot of apple and the ripe rot of grapes. Cross inoculations have definitely proven

that the fungus can go back and forth from the apple to the sweet pea and vice versa. Anthracnose begins its destructive work early, even in the seedling stage.

Chætomium Root Rot

Caused by *Chætomium spirochæte* Pratt.

This disease is of minor importance. It is found on plants weakened by poor cultural conditions, such as overwatering. The symptoms of this trouble greatly resemble the injury from Thielavia root rot. The only way, however, to tell them apart is microscopically.

Fusarium Wilt

Caused by *Fusarium lathyri* Taub.

Symptoms. This disease is of much greater importance to greenhouse men than root rot. The writer has known of instances where the disease has ruined the entire crop of indoor sweet peas. After several resowings, the owners gave up in despair any further attempt to grow them. Florists should do everything to prevent the introduction of the disease into the house. In places where this disease has made its appearance the growing of greenhouse sweet peas had to be abandoned within less than two years. The disease produces a sudden flagging of the leaves which is accompanied by a wilting and collapse of the seedlings (fig. 70, c.). Usually, upon sowing the seed, a fair percentage germinate and reach a height of about eight to ten inches, when they

are attacked by the fungus. If the collapsed seedlings are allowed to remain on the ground, the dead stems will soon be covered with the sickle-shaped spores of the Fusarium fungus. Eventually the dead tissue rots, attracting small fruit flies, which begin to distribute the spores to different places in the same house. The trouble usually appears in widely separated spots on the bench. These spots, however, quickly spread, involving the entire bed, the plants of which may suddenly assume a wilted appearance. Here and there, however, and in the same bench, a few plants remain alive and keep on growing in spite of the disease.

The Organism. The mycelium of the fungus is hyaline, septate, and branched. At an early age the hyphæ begin to form chlamydospores. These are round hyaline bodies filled with oil globules and are formed in the center of the hypha, whereupon the contents of the cell collects into the chlamydospores. Usually, the chlamydospores are also borne at the tip end of the hyphæ in chains of twos, threes and even fours. Old cultures are practically one mass of chlamydospores. There are also two spore forms present, which appear as early as the third day in the pure culture. These comprise microconidia which are fairly abundant and macroconidia, varying from two, three to four celled. The average form of macronidia is the three celled. Both micro- and macroconidia are hyaline and smooth. In old cultures the macroconidia shrink so that the septa become slightly pronounced. These old ma-

croconidia soon lose their protoplasm or let it break up until it presents a granular appearance. In young cultures, the outer wall of the chlamydospore is smooth, but in old cultures it becomes slightly warty or covered with minute points. No perfect stage has been found to accompany this fungus either in pure culture or on the host. This disease may be controlled by the steam method of sterilization.

Root Rot

Caused by *Rhizoctonia solani* Kuhn.

Symptoms. This trouble is of considerable importance to greenhouse men. The disease may destroy the entire stand, or cause it to be uneven, thus necessitating several resowings. Severely infected plants have practically no root system (fig. 71, b.). In less infected plants only one or two rootlets may be destroyed. The fungus produces a browning effect of the root before total destruction sets in. In very early stages of infection the seedlings are seen to have a wilted appearance; as the disease progresses the infected seedlings fall over and collapse. The fungus is not confined to the roots alone. It is often seen to work its way up the stem and produce a constricted area marking it off from the healthy part. As the fungus is a soil organism, it is usually introduced with manure, infection taking place at any part of the roots or stems. In the latter case reddish sunken spots are observed at the base. Root rot is primarily a seedling disease, although older

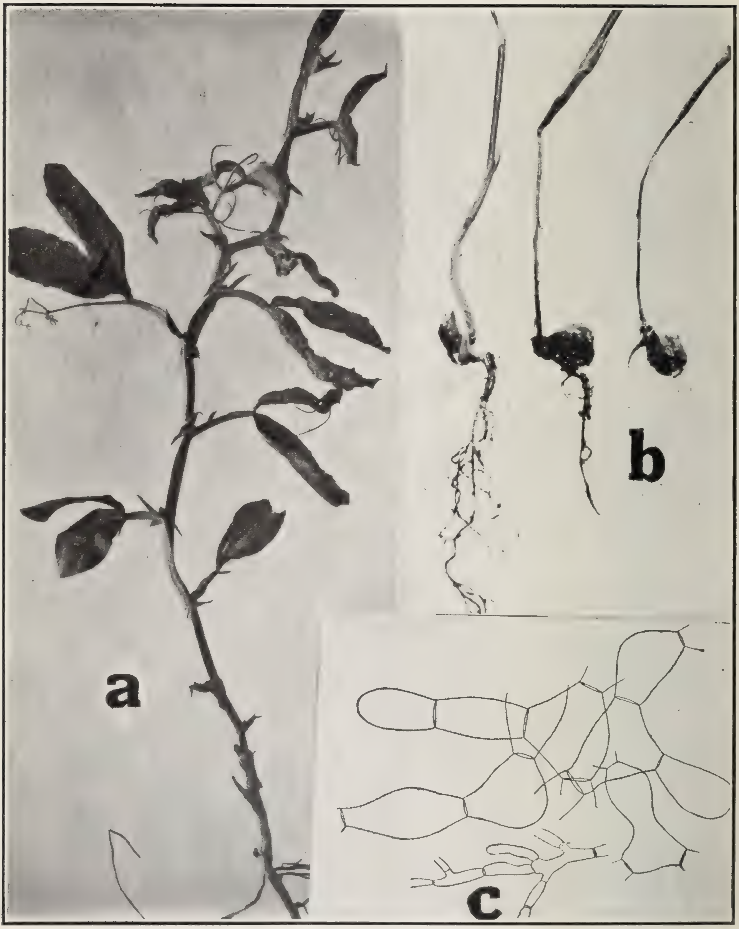

FIG. 71. SWEET PEA DISEASES.

a. Mosaic. *b*. Rhizoctonia root rot, *c*. mycelium of sweet pea Rhizoctonia.

plants, too, may be affected. Such plants linger for some time but are valueless. *Corticum vagum* is a soil fungus which attacks a number of other greenhouse as well as outdoor plants. In this case, the organism (fig. 71, c) either produces a damping off among young seedlings, or deep cambium lesions on the stem. With sweet peas the injury is the same. Root rot is introduced in the greenhouse with infected soil or manure. Overwatering and a sour condition of the soil favor the disease. For a description of the causal organism and method of control, see p. 20.

Root Knot or Nematode

Caused by *Heterodera radicicola* (Greef) Muller.

Symptoms. The disease is characterized by swellings on the roots (fig. 70, d.). These are either small swellings formed singly, in pairs, or in strings, thus giving the affected root a beaded appearance. Again, the swellings may be very large so as to be mistaken for root nodules. However, these galls cannot be mistaken for the normal root nodules, because the latter are lobed and are attached at one end, whereas the root gall produces a swelling of the entire surface of the part affected. Infected plants usually linger for a long time, but they can be distinguished by a thin growth and yellow, sickly looking leaves and stems. The disease is introduced with infected manure or with compost. For a description of the causal organism and methods of control, see p. 23.

CHAPTER 27

TULIPS (*Tulipa suaveolens gesneriana*)

Cultural Considerations. Indoor tulips are grown in much the same way as hyacinths (see p. 266). As blossoms appear, they should be put under partial shade. The petals are very delicate and are subject to burning or wilting when exposed to direct sunlight.

Diseases of the Tulip

Tulips are subject to few but serious diseases.

Blindness

Cause, unknown.

Blindness in tulips is a trouble which results in a failure of apparently normal bulbs to produce flowers (fig. 72, a.). A blind tulip is distinguished from a normal plant by having a leaf scale only. This condition is prevalent where bulbs of small size are used. The cause of blindness, which is being investigated by Stout,* is still undiscovered. Tulip bulbs which have bloomed well the previous year may become blind the second season. These same bulbs, however, may again bloom the third season.

* Stout, A. B., Jour. Hort. Soc. of New York 2: 201-206, 1917.

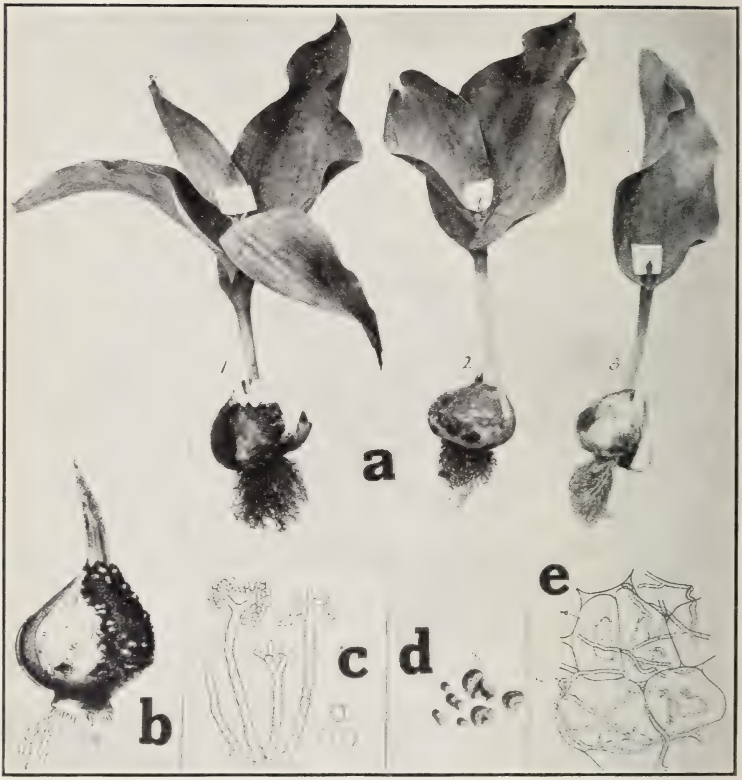

FIG. 72. TULIP DISEASES.
a. Tulip blindness, *b-e.* Botrytis rot.

This would seem to indicate that blindness does not necessarily mean run-down bulbs. It is very likely that the treatment during the curing, storage, or planting to a certain extent predetermines blindness.

Smut

Caused by *Ustilago tulipæ* (H.) Wint.

Like the tulip rust, the smut is of little or no economic importance. Very little is known about either the disease or the causal organism.

Rust

There are two kinds of rust on tulip leaves. Each of these is caused by two species of Puccinia, namely, *P. tulipæ Schw.* and *P. prostii.* Very little is known of these rusts; fortunately, also, they are of little economic importance.

Bulb Rot

Caused by *Sclerotinia parasitica* Massee.

Symptoms. The rot seems to be confined to the scales of the bulb only. The plate as well as the roots remains unaffected. When a tulip bulb is cut open, the scales are found to be more or less softened, grayish, water-soaked, and the inner part to be more or less rotted. As the rot progresses, the outer scales become covered with a mold which forms olive brown, velvety patches (fig. 72, b.). This is made

up of the summer spores of the fungus. Late , the outer scales become covered with small hard f ıngus bodies, sclerotia (fig. 72, d.). Besides the tu..p, the same disease may also attack Narcissus pseudo-narcissus, Galanthus nivalis, and Crocus vernus.

The Organism. The causal organism has two spore stages, the summer stage, *Botrytis parasitica* Cavara (fig. 72, c), and the winter or ascus stage, *Sclerotinia parasitica* Massee.*

Control. Since the causal organism is introduced with the soil, steam sterilization of the latter is recommended. All infected material should be destroyed by fire. Care should be given to the watering and ventilation.

Sclerotium Rot

Caused by *Sclerotium tuliparum* Kleb.

The rot of tulip bulbs which is caused by the above organism has not as yet attained economic importance in this country. Very little is known of the disease or of the causal organisms. Hopkins † states that the sclerotia of *Sclerotium tuliparum* are much larger than those of *Botrytis parasitica*, the latter of which are small, the size of a pin head.

Sclerotium Rot

Caused by Sclerotium tulipæ Lib.

This trouble was found by Seaver ‡ on out-of-

* Massee, G., A Text-book of Plant Diseases: 158-159, 1903 (London).

† Hopkins, E. F., Phytopath. 8:75, 1918.

‡ Seaver, F. L., Jour. N. Y. Bot. Gard. 18:186-188, 1917.

doors tulips. It is doubtful whether it will prove a serious drawback in the greenhouse. The causal fungus causes a rotting of the bulbs, and seems also to be involved in at least one form of blindness. In the latter case, the fungus is found on the young bud which fails to develop and finally rots off. It is very probable that *Sclerotium tulipæ* Lib., *S. tuliparum* Kleb., and *S. bulborum*, all of which have been found by various workers on tulips, are in reality but one and the same fungus.

The Violet (*Viola Odorata*)

Cultural Considerations. With violets the form of the house is not of great importance. In general, however, houses devoted to violets should be constructed on the even span model. A three-quarter span house furnishes too strong a sunlight.

Violets require an abundance of fresh air. Solid beds are preferred to the raised ones. In a house twenty-two feet wide there should be three walks, two and one-half feet wide. Each of the two outer beds should be one foot and nine inches in width, while each of the two inner beds should be seven feet wide.

The temperature at night should never be raised higher than 45 degrees F. for the double flowered varieties, and 45 to 50 degrees F. for the single flowered varieties. The day temperature should never run higher than 60 to 65 degrees F. Violets thrive very poorly under high temperatures. If the mer-

cury rises above 65 degrees, ventilation should be resorted to in order to lower the temperature. High temperatures force the plants to foliage with a deterioration in blossoms. Violets thrive in a soil that is moist but well drained. The soil should be watered enough to keep it moist at all times, but it should never remain saturated for any length of time. Violets should be given all the ventilation possible every time the weather permits it.

Diseases of the Violet

Violets under glass are subject to numerous diseases. Success with this crop requires that these troubles be kept in check to a minimum.

Cladochytrium Root Rot

Caused by *Cladochytrium violæ* Berl.

This trouble is found in Europe, where it was first described by Berlese.* It has not yet been reported in the United States. This disease is manifested as swellings on the roots. The parasite is intercellular with branched mycelial threads. The globose zoosporangium terminates with an open tube through which the zoospores escape. Resting or sexual spores have not been recorded for this species. It is not likely that it will become an active parasite of forced violets.

* Berlese, A. N., Riv. Patol. Veg. 7:167-172, 1901.

Downy Mildew

Caused by *Peronospora violæ* De By.

Downy mildew produces indefinite spots on the leaves. In general appearance this trouble resembles that of the grape. The downy pale violet growth on the spot consists of a layer of the conidiophores. These are short, many times branched with small ultimate branchlets. The conidia are short and elliptic.

Smut

Caused by *Urocystis violæ* (Sow.) F. de W.

Symptoms. The disease produces prominent irregular swellings or blisters on root stalks, stems, petioles, and leaves. Soon the swellings rupture, exposing black-brown masses, and giving the affected plant a smutty appearance.

The Organism. The spore balls are reddish brown and oblong to partly spherical. The sterile cells are yellowish with age, but the fertile cells are reddish to light brown. The chlamydospores appear in balls of 4 to 8 spores.

Control. Smut is usually brought in with infected cuttings or plants from out-of-doors. These, therefore, should be avoided. Infected plants should be destroyed by fire.

Rust

Caused by *Puccinia violæ* (Schum) D. C.

Symptoms. The rust is characterized by circular

patches, the presence of which greatly distorts the attacked parts. All the three stages of the causal organism, æcia, uredinia, and the telia are present on the same fungus.

The Organism. The æciospores are orange yellow, subglobose, and finely warty. The uredospores are roundish and brown, possessing tiny warts. The teleutospores are black, elliptic to oblong, with thickened tip, and with a very slight constriction.

Control. Violet rust is most prevalent on out-of-door plants, especially on the wild varieties. The disease is not of economic importance on indoor violets.

Crown Rot

Caused by *Sclerotinia libertiana* Fcl.

This disease causes a rot of the crown as well as of the runners. This trouble is common in the cutting bed in which case it produces a damping off. In either case, the affected parts become soft and slimy. The disease is found only in leaky houses, or in beds with leaky water pipes. Attention to these points will check the trouble. For further description of the causal organism, see lettuce, p. 151.

Thielavia Root Rot

Caused by *Thielavia basicola* (B. and Br.) Zopf.

Thielavia root rot is perhaps one of the most important troubles of greenhouse violet. The disease also attacks sweet peas, cyclamens, and asters.

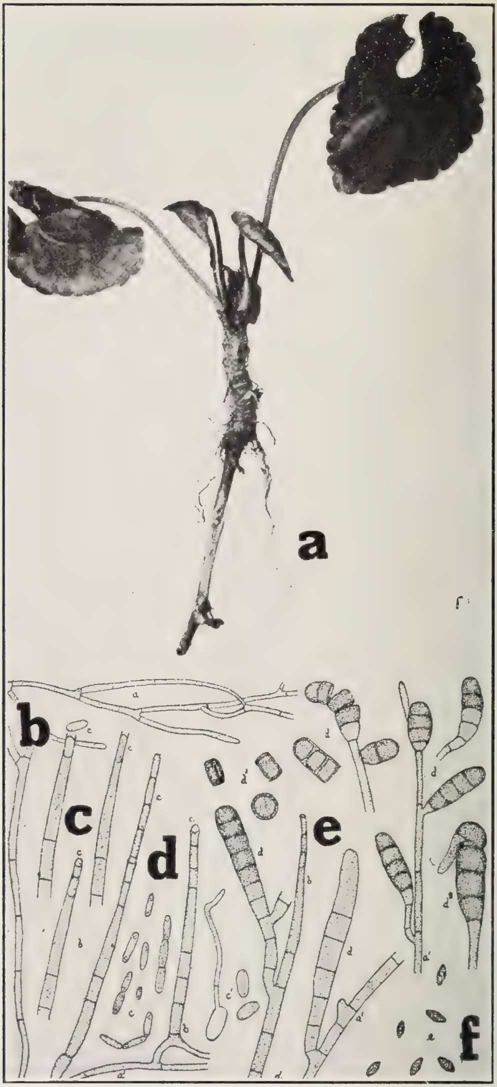

FIG. 73. VIOLET DISEASES.

a. Thielavia root rot (after Reddick), *b-f* stages of the Thielavia fungus, *b.* mycelium, *c* and *d.* endospores, *e.* and *f.* chlamydospores.

Symptoms. Diseased plants are dwarfed, with crinkled foliage, of a sickly yellow color. A closer examination will show that the seat of the trouble is confined to the underground stems and roots. In damp soils the former are often cracked, distorted, or covered with water-soaked spots. On the roots occur numerous brown or black lesions which eventually girdle them. This girdling may take place at several points. Often the roots rot off (fig. 73, a), and all that remains is merely a short stub. The runners like the roots are often spotted or girdled in many places. The lesions first appear as a brown water-soaked spot which enlarges, the center becoming whitish and the margin black. On the leaf petioles lesions are often produced which are similar to those formed on the runners.

The Organism. Thielavia basicola has several spore stages. The chlamydospores are composed of from four to eight segments (fig. 73, e and f.). The basal segments are usually empty. The others above are dark brown, with thick walls and are able to break up into individual cells each of which is capable of germination. Another spore type is the spore generating tube from within which are pushed out small cylindrical bodies with thin walls, that are known as endoconidia (fig. 73, c and d.). The latter too are capable of germination. The third spore form is the ascospores. These are borne in sacks within a main globose fruiting body known as the perithecium. The latter stage, however, is seldom found on diseased violets. The fungus is

generally carried from year to year as chlamydospores in remnants of infected tissue in the soil or in the compost pile.

Control. The fact that the harboring of chlamydospores in the compost is one of the means by which the causal organism is brought into the greenhouse at once suggests soil sterilization as a means of control. This disease is often carried unconsciously with affected cuttings. From there the sand used for rooting the cuttings becomes infected. If the same sand should be used over again it will infect all cuttings planted there. Where there are no facilities for soil sterilization the grower should make it a practice to use virgin sand every year. However, a safer method is to disinfect the soil with formaldehyde. Reddick * recommends the use of 1 pint of commercial formaldehyde (40 per cent pure) to 12½ gallons of water. This solution is then used at the rate of 1 gallon to each square foot of bed space. Lime should not be used for violet beds, because lime favors the development of Thielavia. Careful attention should also be given to the watering of the plants. An excess of moisture in the soil favors the disease. It is doubtful that spraying will have any effect in controlling this trouble.

Anthracnose

Caused by *Glœosporium violæ* B. and Br.

This disease attacks the edges of the leaves, start-

*Reddick, D. Trans. Mass. Hort. Soc.: 85-102, 1913.

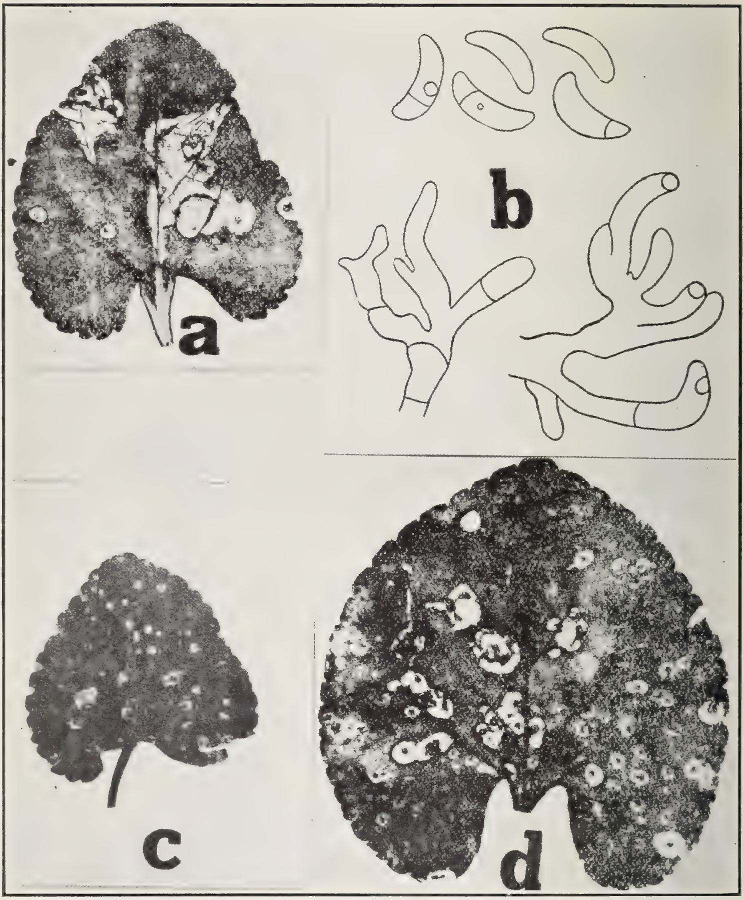

FIG. 74. VIOLET DISEASES.

a. Phyllosticta leaf spot (after Halsted), *b.* conidiophores and conidia of *Marsonia violæ* (after Jones, L. R.), *c.* speck anthracnose (after Jones and Giddings), *d.* Cercospora leaf spot (after Halsted).

ing as an irregular discoloration which extends inwards. Affected foliage rots and becomes unsightly. The acervuli are thin and few in numbers; the conidia are yellowish.

Phyllosticta Leaf Spot

Caused by *Phyllosticta violæ* Desm.

Symptoms. This disease is characterized by numerous circular whitish spots, averaging about an eighth of an inch in diameter. Often the spots run together and involve the entire leaf (fig. 74, a.). The pycnidia are found on the dead tissue of the spots. The disease is commonly found on out-of-doors violets, but it is also met with under greenhouse conditions. The same disease also attacks the pansy.

Organism. The pycnidia of the fungus are brown, minute, and numerous. The spores are minute and subcylindrical.

Control. It is probable that spraying with a standard fungicide will control the disease. All infected material should be destroyed by fire.

Ascochyta Leaf Spot

Caused by *Ascochyta violæ* Sacc.

This disease is characterized by scorched appearing patches on the leaves. The affected plants soon become unsightly while the blossoms produced are stunted and valueless commercially. Little is known

of the causal organism. Destruction by fire of diseased plants and diseased material is recommended.

Speck Anthracnose

Caused by *Marsonia violæ* (Pass.) Sacc.

Symptoms. The presence of the disease is marked by numerous small raised, black or brown colored spots on the upper surface of the leaf (fig. 74, c.). The disease, so far as is known, is confined to the leaves, and has not yet proved to be very serious. Jones and Giddings * believe that the disease was probably introduced from Europe with imported cuttings.

The Organism. Within the minute spots may be found the acervuli in which the spores are borne (fig. 74, b.). The spores are curved and one or two celled. The spetum is generally nearer one of the tips than in the center.

Control. The disease may be kept in check by spraying with a standard fungicide.

White Mold

Caused by *Zygodesmus albidus* Ell. and Halst.

This trouble is generally manifested as a white flourlike coat over the leaves. Little is known of the causal organism, nor has it proven so far of any serious consequence.

* Jones, L. R., and Giddings, N. J., Vermont Agr. Expt. Sta., Nineteenth Ann. Rept.: 234-235, 1906.

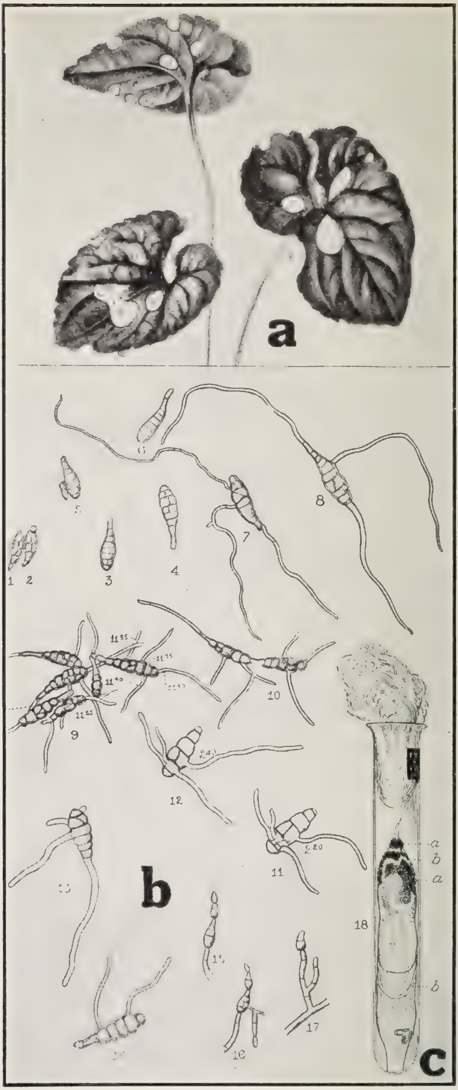

FIG. 75. VIOLET DISEASES.

a. Alternaria leaf spot, *b.* Spore stages of *Alternaria violæ*, *c.* pure culture of *A. violæ* (*a-c* after Dorsett).

Spot Disease

Caused by *Alternaria violæ* Gal. and Dors.

Spot disease is often known under the names of leaf spot, blight, smallpox, and rust. The disease constitutes a serious drawback to indoor violet culture. In 1900, the violet industry of Alexandria, Va., had been practically abandoned because of leaf spot. From five to eight years before the appearance of the trouble the glass area devoted to violet in that vicinity was estimated at from 50,000 to 75,000 square feet of glass. The term "violet disease" is the one generally applied by the average grower.

Symptoms. The disease attacks violets in practically every stage of their development. Even cuttings in the propagating bed are not immune from it. Generally plants which make rapid growth, but which are soft and succulent, are most subject to leaf spot. On the leaves the spots are at first small, but definite, usually circular, greenish, or whitish resembling the sting of some insect. The spots soon enlarge and the light central portion becomes surrounded by a narrow ring of discolored tissue, which is black or brown at first, but which fades as the spots become older (fig. 75, a.). Young spots are water soaked and semitransparent. In a few days, however, the spots become dry, bleached, yellowish gray to white or pure white. Occasionally young spots fail to develop, dry and fall out, leaving a shot-hole appearance. Usually there are several spots on a

leaf. These upon enlarging meet and coalesce, giving the appearance of large, white blotches. The spores of the causal fungus develop on the spot under moist conditions only.

The Organism. The fungus grows well on agar media, usually in concentric rings. The color of the mycelium is at first grayish white, but as the spores are formed the entire growth takes on an olivaceous tint due to the color of the spores. The conidiophores of the fungus are borne in clusters and are erect, pale olivaceous, and septate. The conidia are borne in chains on the tips of the conidiophores, and are flask shaped, muriform, and olivaceous (fig. 75, b and c.).

Control. To control this disease it is necessary to have a clear idea of the factors which favor leaf spot under greenhouse conditions. Dorsett * enumerates the following:

"1. Not keeping the houses or frames clean, fresh, and sweet by frequently repairing and painting them, and by removing and destroying rubbish of all kinds as soon as it appears.

"2. Not keeping the plants clean and in the best possible growing condition at all times.

"3. Not selecting stock from strong, vigorous plants that have been entirely free from disease.

"4. Not being careful to select only strong, vigorous, healthy stock from the cutting bed for planting in the spring.

* Dorsett, P. H., U. S. Dept. of Agr. Div. Veg. Phys. and Path., Bul. 23: 7-16, 1900.

"5. Not giving the proper attention to the selection and preparation of the soil, to date and method of planting, and to care and cultivation of the plants during the growing season.

"6. Not giving due consideration to the several varieties and their adaptability to the soil and location in which they are grown."

It is evident therefore that these are important points to which the grower must give careful attention. In addition and as far as possible preference should be given to those varieties which are resistant to leaf spot. Marie Louise, for instance, is a very susceptible variety. On the other hand, Lady Hume Campbell is said to be resistant.

Since the spores of the causal organism may be introduced with the soil, steam sterilization is recommended. Proper attention also should be given to the ventilation, watering, and heating of the houses.

Cercospora Leaf Spot

Caused by *Cercospora violæ* Sacc.

The trouble is characterized by large, dead, ashy spots on the leaves (fig. 74, d.). The centers of the spots are darker, due to the presence of the conidiophores. These are dark and short. The conidia are rod shaped, hyaline, long, slender, and many septate.

Root Rot

Caused by *Fusarium violæ* Wolf.

Symptoms. This disease is characterized by a

sudden dying of the plants. Upon pulling it up we will find slightly sunken areas on the stem just above ground. The root system is generally destroyed, with the exception of a small stub.

The Organism. Fusarium violæ was first described by Wolf.* The sporodochia of the fungus are borne within the stems. The macrospores are hyaline, cycle shaped, 3-5 septate. The microconidia are small, continuous; condiophores short.

Control. The disease is likely to occur where fresh barnyard manure is incorporated in the soil before planting. Care should therefore be taken to use only well rotted manure. Infected soils should be steam sterilized, or disinfected with formaldehyde (see pp. 32-43).

WALLFLOWER (*Cheiranthus cheiri*)

Cultural Considerations. Wall flowers require a cool house, with a night temperature not higher than 45 to 50 degrees F. They thrive best when supplied with an abundance of water and ventilation.

Fungi recorded on the wallflower. The wallflower is considered a very hardy flower, and is easily forced. The following fungi recorded on this host may prove serious:

Cercospora cheiranthi Sacc., *Peronospora parasitica* (Pers.) De. By.

* Wolf, F. A., Mycologia 11: 19-22, 1910.

PART V

GREENHOUSE PESTS

FIG. 76.

a. Adult red spider, *b*. cuttings of California privet attacked by red spider, showing web formation.

CHAPTER 28

PLANT PESTS

Arachnides

Red Spider. Tetranchyus bimaculatus Harw.

Red spiders or spinning mites (fig. 76, b) are very troublesome to greenhouse crops; cucumbers are especially attacked by them. Eggplants and tomatoes are next in preference. Of the flowering plants, roses, violets, sweet peas, carnations, and chrysanthemums are also favorite hosts. The plants in the vicinity of greenhouses which are subject to the attacks of red spiders are beans, eggplants, celery, tomatoes, strawberries, clover, grasses, and weeds.

Nature of Injury. The red spiders (fig. 76, a) feed on the under side of the leaves by puncturing and extracting the chlorophyll and plant juices in the cells of the punctured area. This soon results in small dead areas which become apparent as small whitish specks on the upper part of the leaf. In advanced stages, affected foliage become pale, whitish, transparent, and covered with minute dead pitted specks usually arranged in clusters.

Control. Red spiders are at their best in hot, dry houses. They may be readily controlled by syringing with water. A strong but fine water spray de-

stroys their web and drives them off since red spiders cannot thrive under moist conditions. Plants with hardy foliage may successfully be rid of the spider by spraying with a solution composed of one-half pint of "Nicofume" liquid, and two quarts of concentrated lime sulphur in 25 gallons of water. One-half ounce of salt dissolved in one gallon of water seems to control red spider on carnations. This, however, may burn the foliage of most other plants.

Investigations by Vinal * seem to show that no fumigant was efficient in killing red spiders without severely hurting cucumber plants. Sulphur burned to form sulphur dioxide proved very effective in killing all stages of mites. However, since this gas is very deadly to plant life, it can only be used as a fumigant to free empty houses from spider infestation. For the control of all stages above the egg stage, spraying with lemon oil or linseed oil emulsion proved very effective. Lemon oil may be used at the rate of 1 part in 20 parts of water, and applied thoroughly. For directions to prepare linseed oil emulsion, see p. 399.

Mites (*Tarsonemus pallidus* Banks)

Mites (fig. 78, a and b) are really closely related to red spiders. The species *Tarsonemus pallidus* is of particular interest to greenhouse growers because it attacks cyclamens, snapdragons, geraniums, and chrysanthemums.

* Vinal, S. C., Mass. (Amherst) Agr. Expt. Sta., Bul. 179: 153-182, 1917.

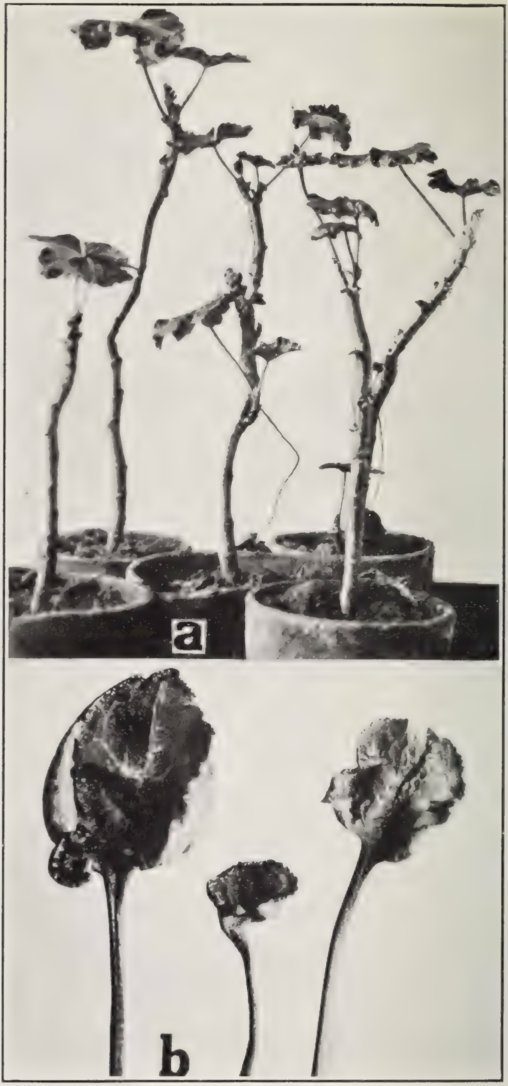

Fig. 77.

a. Mite injury of geranium, *b.* of cyclamen.

Nature of Injury. On the cyclamen (fig. 77, b), the work of the mites produces a gall. Usually both leaf and flower buds are badly affected. Infested plants are stunted, the foliage distorted, and the blossoms discolored. Instead of the normal soft pink or red, the petals become blotched and streaked; ultimately the flower wilts and dies prematurely. On the geranium (fig. 77, a, and fig. 79, b) the attack by the mite causes the foliage to curl and to drop prematurely. Often, too, the injury becomes noticeable as scorched spots on the leaves. Injury is most severe when the plants are crowded, the leaves touching each other, and the humidity high. In this respect, therefore, the mite differs from the red spider, in that the latter only thrives under droughty conditions. On the snapdragons (fig. 78, a and b, fig. 79, a) and chrysanthemums the attacked foliage becomes curled and distorted, and the flower buds, too, swell somewhat, and become distorted and useless. The same pest also attacks the blackberry out of doors (fig. 79, c.).

Control. At first, mites seem to attack the cyclamen during dry weather. Later, however, poor cultivation, poor ventilation, and excessive moisture in the house seem to encourage the work of the pest.

With geraniums some varieties seem to be more resistant than others. Garman * states that the varieties Le Pilote, Jean Vroud, S. A. Nutt, Alphonse Ricard, Madame Kowalevski, Baron Grubissich,

* Garman, P., Maryland Agr. Expt. Sta., Bul. 208: 327-342, 1917.

Maryland, Beaute Poitevine, Mme. Laudry are all susceptible to the attacks of the mites. On the other hand, the variety Le Favorite seems to be immune. It is not known whether or not there are resistant varieties of cyclamen, chrysanthemum, or snapdragon. Because of the extremely primitive respiratory system of mites, it is difficult to keep them in check by fumigation with various gases. It is safer therefore to resort to spraying. However, when a plant becomes badly infested, no attempt should be made to save it. It will be cheaper to destroy it by fire. Dusting with tobacco or sulphur will do little good. Moznette * obtained good results by dipping the plants in an oil emulsion called Yel-ros mixed in the ratio of one part of Yel-ros to forty parts of water. Yel-ros contains a good deal of Xylol which is penetrating. This treatment, however, is recommended for older plants. Young plants may be greatly injured by burning. "Black leaf 40" and water in the ratio of 1 to 1,000, or of one teaspoonful to a gallon of water will effectively control the mite. By adding three to four pounds of ordinary soap to each 100 gallons of the above solution, it will be made to adhere better to the treated plants. Spraying should begin before the mites attack the plants and should be continued every ten days until the flower buds are ready to open. At this stage the spraying should cease as otherwise the petals may be discolored.

* Moznette, G. F., U. S. Dept. of Agr., Jour. Agr. Research 10:373-390, 1917.

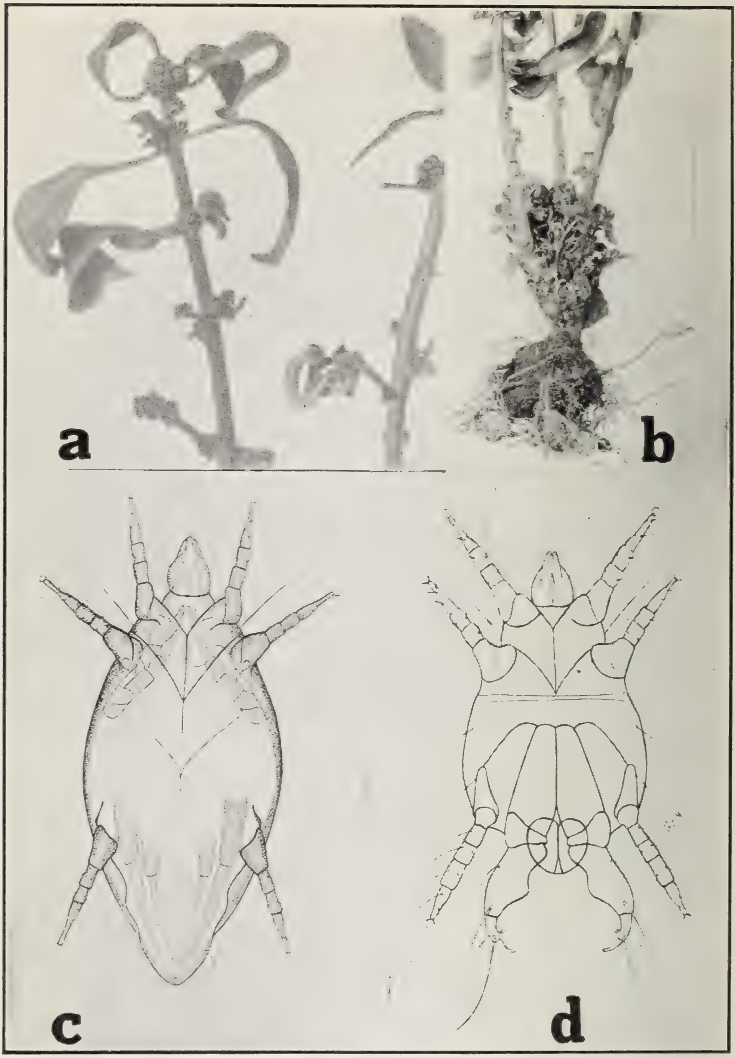

FIG. 78.

a and *b*. Snapdragon mite injury, *c* and *d*. adult male and female mites.

CHAPTER 29

GREENHOUSE THRIPS (*Heliothrips hæmorrhoidalis* Bou.)

GREENHOUSE thrips often cause considerable damage to ornamentals, while their presence may not always be detected. The damage caused by thrips is confined to the foliage. The adult and the larvæ of the thrips feed by puncturing and lacerating the epidermis and by sucking the plant juices. The injury at first becomes apparent on the older leaves, and later spreads to the younger ones. The trouble first appears on the under side of the leaves in the form of minute white epidermal spots. Later, as the spots become more numerous, they unite, forming large blotches. At this stage, the injury becomes apparent on the upper part of the leaves as a distortion between the lateral veins, and by wilting and dying of the edges. Both sides of the infested foliage soon become covered with minute drops of a reddish fluid which finally changes to black. These drops are voided by the thrips. Affected foliage becomes white and drops off prematurely. In the greenhouse, thrips may attack azalea, aspidium, croton, dahlia, phlox, verbena, pink, ferns, palms, ficus, and fuchias.

Control. The easiest way to keep this pest in

check is in burning nicotine papers at the rate of 2 sheets to every 1,000 cubic feet of greenhouse space. Fumigation is best performed at night in a moist atmosphere. Early in the morning the treated house is opened and thoroughly aired. Fumigation with nicotine liquid extracts is also effective in controlling thrips. Russell * recommends the use of one ounce of liquid nicotine (containing 40 per cent. nicotine) to every 1,000 cubic feet of greenhouse space, or from one and a half to two ounces of the weaker strengths. The liquid is evaporated over small lamps or stoves, and to prevent scorching is diluted with water. Greenhouse thrips may also be kept in check by fumigation with hydrocyanic-acid gas. For directions, see p. 385.

Mealy Bugs (*Pseudococcus sp.*)

Mealy bugs are really scales without armor. They are sprinkled over with a white mealy wax or powder which gives them the name. In the greenhouse there seems to be but two species of importance, namely, *Pseudococcus citri* and *P. longispinus*.

Control. The easiest way to keep this pest in check is to liberally syringe the plants with water at a fair pressure. This will wash the insects off the plants and permanently dislodge them. Spraying with a mixture of one part nicotine sulphate to 750 parts of water will also keep them in check. Fumi-

* Russell, H. M., U. S. Dept. of Agr., Bureau Entomology Circ. 151: 1-9, 1912.

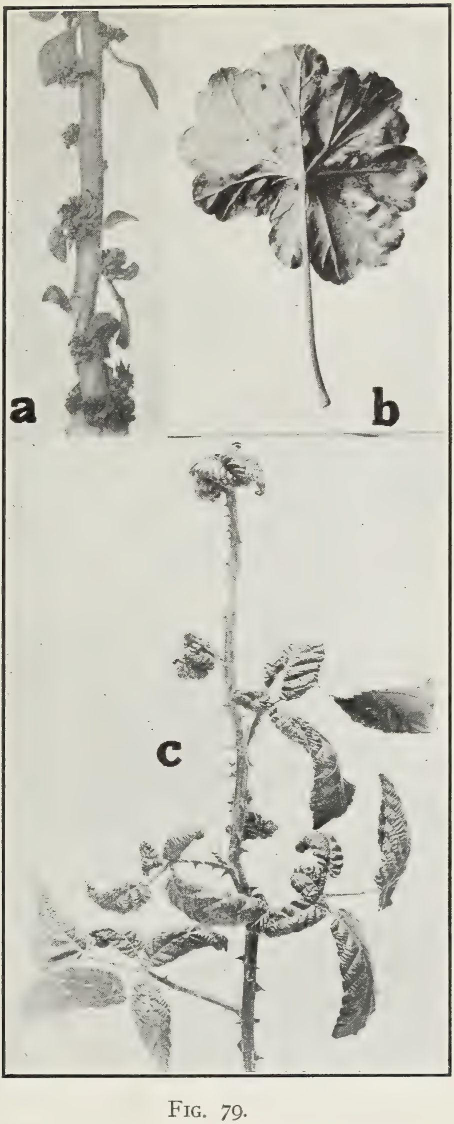

Fig. 79.

a. and *b.* Snapdragon and geranium injury (after Garner), *c.* mite injury of blackberry.

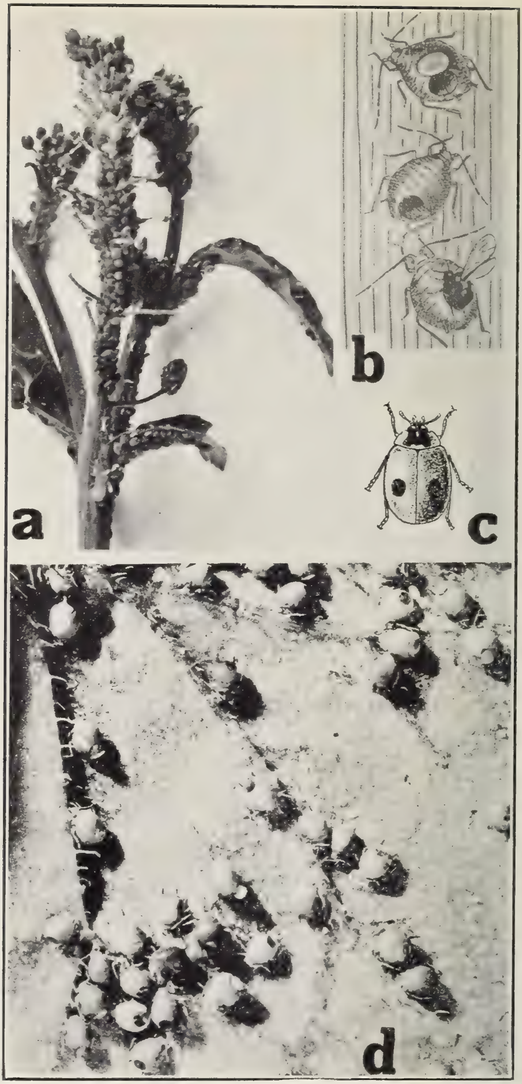

Fig. 80.

a. Mustard plant badly infected with the green aphid, *b* and *d*. parasitized aphids, the circular holes on the backs are openings through which the adult *Aphidius testaceipes* emerged, *c*. lady beetle.

gation with five ounces of cyanide to each 1,000 cubic feet of space for one hour will also be effective.

Scale Insects

There are various scale insects which attack greenhouse plants. The black scale, *Lecanium oleæ*, attacks the geranium and roses. *Lecanium tessellatum* attacks palms. *Aspidiatus nerii* attacks a large and varied number of house plants.

Control. The safest method of treatment is fumigation with hydrocyanic-acid gas. For directions, see p. 385.

White Fly (*Alleyrodes vaporaiorum West*)

The white fly is considered one of the worst pests of some greenhouse crops. The plants most affected are cucumber, lettuce, tomatoes, eggplants, chrysanthemums, coleus, geraniums, and roses. The pest injures the plants by attacking the underside of the leaves and by sucking the tissue juices. The insect deposits a sweetish, sticky substance which tends to clog the stomata of the leaves, and frequently serves as the host for a sooty mold.

Control. White flies may be controlled by fumigating with hydrocyanic-acid gas. For directions, see p. 385.

Plant Lice or Aphids (*Aphididæ*)

Plant lice (fig. 80, a) derive their food by sucking the plant juice. In the greenhouse there seem

to be four important aphids which attack plants. The melon aphis (*Aphis gossypii*) is a general feeder and attacks a large number of plants. The green aphis (*Nectorophora rosæ*) seems to attack the rose only. The brown aphis (*Rhopalosiphum violæ*) attacks the violets. The black aphis (*Nectorophora chrysanthemicoleus*) attacks the chrysanthemum. The following table by Davis * is a list of plant lice which are known to attack ornamentals in the greenhouse:

* Davis, G. C., Michigan Agr. Expt. Sta., Special Bul. 2: 5-43, 1896.

TABLE 18

List of Aphids Attacking Ornamentals

Name of Plant	*Name of Aphis*	*Color of the Species*
Amaranthus sp.	Myzus achyrantes, Mon.	Pale green with black stripes
Asparagus officinalis	Rhopalosiphum dianthi Schk.	Thorax black, abdomen mostly green
Callistephus chinensis	Aphis middletonii, Thos. (on roots)	Apterous, leaden gray
	Siphonophora sp. Sirren	Yellowish-green
Caladium esculentum	Rhopalosiphum dianthi Schr	Thorax black, abdomen mostly green
	Aphis malvæ, Walk	
Calendula officinalis	Aphis calendulicola, Mon.	Apterous, uniform pale green
	Nectarophora calendulæ Mon	Black or brownish-black
	Nectarophora calendulella Mon.	Apterous, pale whitish-green
Richardia africana	Rhopalosiphum dianthi Schr.	Thorax black abdomen mostly green
Dianthus caryophyllus	Rhopalosiphum dianthi Schr.	Thorax black, abdomen mostly green
	Phorodon cyanoglossi Will.	Green
Chrysanthemum sinense	Aphis chrysanthemicola Will.	Green
	Siphonophora chrysanthemicolens Will	Shining black
Cuphea ignea (platycentra)	Aphis malva, Walk.	
Coleus Blumei	Siphonophora rosæ Linn	Black, abdomen mostly green
Cyranthus annuus	Rhopalosiphum dianthi Schrk.	Thorax black, abdomen mostly green
Narcissus sp.	Siphonophora sp. Sirren.	Black and green
Hedera helix	Siphonophora rosæ, Linn.	Black, abdomen mostly green
Myosotis dissitiflora / Myosotis palustris	Phorodon cyanoglossi Will.	Green
Pelargonium zonal	Siphonophora pelargonii, Kalb	Thorax black, abdomen mostly green
Senecio scandens	Rhopalosiphum dianthi Schr.	Black, abdomen reddish-brown
Grindelia squarrosa	Schizoneura corni, Fabr. (on roots)	Grass green
	Siphonphora grindeliæ, Will	Thorax black, abdomen mostly green
Hibiscus rosa-sinensis	Rhopalosiphum dianthi Schr.	
	Aphis malvæ, Walk	
Althæa rosea	Aphis malvæ, Walk	
	Aphis cucumeris, Forbes	Black, abdomen yellowish-green
Lonicera glauca / Lonicera parviflora	Aphis loniceræ, Mon.	Green, headed thorax brownish
	Aphis lonicericola, Will.	Pinkish

TABLE 18 (continued)

Name of Plant	Scientific Name of Aphis	Color of the Species
Iris germanica	Rhopalosiphum dianthi, Schr	Thorax black, abdomen mostly green
	Siphonophora sp. Sirr	Pale yellowish-green
Lilium sp	Siphonophora lilii, Mon	
	Aphis lilicola, Will	Green?
	Rhopalosiphum dianthis, Schr	Thorax black, abdomen mostly green
Adiantum cuneatum, etc	Aphis adianti, Œst	Apterous, lemon yellow
Maurandya Hendersoni	Rhopalosiphum dianthi, chr	Thorax black, abdomen mostly green
Mimulus luteus Mimulus moschatus	Aphis mimuli, Œst	Small, pale greenish, thorax black
Ipomœa grandiflora	Siphonophora sp. Sirren	Pale green
Myrtus communis	Rhopalosiphum dianthi, Schr	Thorax black, abdomen mostly green
Nerium oleander	Aphis neri, Kalt	Bright saffron-yellow
Citrus aurantium	Rhopalosiphum dianthi, Schr	Thorax black, abdomen mostly green
	Aphis citri, Ashm	
	Siphonophora citrifolii, Ashm	
Oxalis cernua lutea et al	Rhopalosiphum dianthi, Schr	Thorax black, abdomen mostly green
	Aphis maidis, Fitch	Black, abdomen, greenish
Solanum jasminoides	Siphonophora solanifolii, Ashm	Apterous, pale yellowish-green
Rosa sp	Siphonophora rosæ, Linn	Black, abdomen mostly green
	Siphonophora rosæ var floridæ, Ashm	
	Siphonophora pallida, Œstl	Olive brown, abdomen pale red
	Myzus rosarum, Walk	Black, abdomen greenish
Viburnum opulus sterilis	Aphis viburni, Scop	Black to dark brown
Euphorbia marginata	Siphonophora euphoricola, Thos	Pale pea-green
Polianthes tuberosa	Rhopalosiphum dianthi, Schr	Thorax black, abdomen mostly green
Tulipa gesneriana	Rhopalosiphum dianthi, Schr	Thorax black, abdomen mostly green
	Rhopalosiphum tulipæ, Thos	Green, with black markings
	Siphonophora tulipæ, Mon	Pale green
Verbena sp	Siphonophora verbenæ, Thos	Apterous, pea-green to yellowish
Ampelopsis 5-folia	Aphis setaria, Thos	Dull black, abdomen brown
	Aphis parthenocissi, Will	Brownish to black

Control. Aphids may be controlled in the same way as thrips (see p. 369). They are also kept in check in nature by lady beetles (fig. 80, c) which feed on them, and by a fly, *Aphidius testaceipes* (fig. 80, b and d). The adult female of this fly lays its eggs in the body of the aphis. The eggs upon hatching give birth to a small legless larva which feeds upon the interior vital parts of the plant louse. When the larva is fully developed it pupates and cuts a circular hole on the top of the body, emerging as a winged insect ready to attack other aphids.

Soil-Infesting Insects

Soils infested with insect pests are as sick as when infested with eelworm or parasitic fungi. The greenhouse man in sowing his seed has often great difficulty in obtaining a good and even stand. Frequently the stand is reduced by fifty per cent. in spite of the many resowings. The cause of this may be traced to the presence in the soil of certain insect pests. Among those dreaded most are: Cutworms (Agrotis sp.), (Lycophotia sp.), (Peridroma sp.); wireworms (Melanotus sp.), and white grubs (Phyllophaga sp.).

Control. Spraying the soil will be of little value in the control of underground insect pests. Fortunately, however, we have more effective means for dealing with them. To destroy wireworms, sow corn which has been soaked for ten days in water containing arsenic or strychnine sulphate before

planting the regular crop. The larvæ will feed on the poisonous corn kernels and die. Another way is to treat the seed with gas (coal) tar.

White grubs may be controlled by the use of bisulphide of carbon.

Cutworms may be controlled by the use of a poisoned bran made as follows: to three ounces of molasses add one gallon of water and sufficient bran to make a fairly stiffened mixture. To this add Paris green or arsenic and stir well into a paste. A heaping teaspoonful of the mixture is scattered here and there over the infested beds.

Ants

Ants are often troublesome in the greenhouse. These may feed on germinating seed or on growing tips of tender plants. A more pernicious habit is the care and protection which they afford to plant lice and mealy bugs.

Control. Ants may be controlled by being fed with a poisoned bait prepared as follows: To 7½ pints of water add one-fourth of an ounce of tartaric acid (crystals), 15 pounds of granulated sugar. Boil this mixture slowly for 30 minutes and allow it to cool. Then slowly dissolve three-fourths of an ounce of sodium arsenate in one-half pint of hot water and allow it to cool. After this is well stirred into the sirup above mentioned, add one and a half pounds of pure honey. This mixture may now be sprayed on paper or boards on the beds. The ants

being fond of sweet foods will be attracted, and upon feeding on it will be poisoned.

Hot House Milliped (*Oxidus gracilis*)

These "thousand legged" little creatures are very common in beds in which have been mixed large quantities of rotted manure or leaf mold. They often attack sprouting seeds, either devouring or seriously injuring them. These millipeds may occasion considerable damage in cucumber beds. The common species is *Oxidus gracilis*. However, another injurious form often met with is *Julus virgatus*.

Control. Gossard * of the Ohio Experiment Station recommends the application of tobacco dust mulch to the infested bed. This is spread out evenly and worked in one-half to one inch deep. A mixture of nicotine sulphate and water in the proportion of 1 to 700 when applied to the infested soil will also help to destroy the millipeds in the beds. They may also be poisoned by placing at various intervals on the beds slices of pumpkin previously dipped with phosphorus rat paste.

Sow Bugs, "Wood Lice," Isopods

Sow bugs are abundant under potted plants or in damp secluded places. Besides feeding on dead animal and vegetable matter, they also feed on living

* Gossard, H. A., Ohio Month. Bul. 3: 55-56, 1918.

plants. They prefer orchids and similar plants because they can hide in the moss and feed on the fibrous roots. Carnations also are often attacked by the same pest.

Control. Tobacco dust and nicotine solutions are ineffective in controlling sow bugs. Sliced pumpkin treated with phosphorus rat paste is an effective remedy.

Slugs

Slugs or snails often cause considerable damage to greenhouse plants. These pests feed at night and usually hide during the day. They secrete a slimy mucus as they travel. By dusting the plants with ashes, lime, or any caustic dust, the latter will adhere to the slime of the body, which upon drying soon exhausts the creatures in their struggle to be freed.

PART VI

METHODS OF CONTROL

CHAPTER 30

METHODS OF CONTROL

From a practical consideration the greenhouse grower is directly concerned in finding control methods to keep the various plant diseases under check. Fortunately, there are numerous methods which if followed out intelligently may be the means of reducing losses to a minimum. These methods may be enumerated as follows:

1. Soil sterilization. This method has been fully discussed under chapter 3, pp. 32-43.
2. Seed treatment, taken up in chapter 8, p. 104.
3. Spraying.
4. Hygiene.

3. Spraying

While the orchardist has learned the necessity of spraying, it is doubtful whether greenhouse growers have sufficiently realized its value. Spraying has two aims: to kill the insect and animal pests, and to control fungous diseases. The substances which are used for the one purpose are without effect on the other.

Insecticides

All animal and insect pests are best controlled by the use of poisonous mixtures applied in the form

of liquid sprays or in powders. Insecticides may be classified as internal or stomach poisons, and external or contact poisons.

(a) Stomach Poisons. Paris green is one of the oldest stomach poisons. When chemically pure, it is composed of copper oxide, acetic acid, and arsenious acid. It destroys cutworms, caterpillars, beetles, grubs, slugs, etc. It should be applied preferably as a liquid, using one pound of the poison and two pounds of lime to two hundred gallons of water. The Paris green tends to sink to the bottom of this mixture, unless constantly stirred while being applied. This chemical is often adulterated with white arsenic, causing it to scorch the treated plants badly. Therefore for greenhouse crops the use of arsenate of lead is to be preferred, since it is less liable to scorch the foliage, and also because it adheres better. Its chemical composition consists of acetate of lead and arsenate of soda. It is applied to the best advantage as a liquid, composed of about three pounds of powdered arsenate or five pounds of paste arsenate to one hundred gallons of water.

Arsenite of zinc may also be used. It is a very finely divided fluffy white powder which can be thoroughly distributed and which adheres well to the foliage. It is intermediate between Paris green and lead arsenate in strength, and costs less than either.

It is essential when arsenicals are used to see that they are correctly labeled, and kept under lock and key, as they are poisonous to both man and animal.

Hellebore or white hellebore is somewhat less dan-

gerous than the arsenicals. However, it loses its insecticidal value by being exposed to the air. It is a specific against slugs.

(b) Contact Poisons. These are used most extensively in the greenhouse.

Water. Every florist appreciates this simple and effective remedy. To be effective in dislodging and destroying soft-bodied insects, it must be thrown with considerable force on all parts of the plants. For this purpose a good nozzle attachment is very necessary. This simple remedy is effective in destroying red spider, white flies, and mealy bugs.

Tobacco. There are few substances which are more extensively used than the many commercially prepared tobacco products. Finely ground tobacco is extensively used as an insecticide, especially for Aphids. The product known as nicofumes is extensively used for indoor fumigation.

Tobacco Decoction. This may be prepared by boiling for one-half hour one pound of tobacco stems in two gallons of water. It is then strained and more water added to replace that which was lost by evaporation during boiling. The liquid is used as a spray against plant lice.

"Black Leaf" and "Black Leaf 40." These are two commercial products. The latter is the more concentrated of the two and is extensively used in the control of sucking insects. The following table by McCue * shows the dilutions that should be

* McCue, C. A., Del. Agr. Expt. Sta., Bul. 97: 17, 1912.

used to give a nicotine content varying from 0.03 to 0.1 per cent.

TABLE 19

Nicotine Contents Percentage	"Black Leaf"		"Black Leaf 40"	
	Parts "Black Leaf"	Parts Water	Parts "Black Leaf 40"	Parts Water
.03%	1	123	1	1600
.04%	1	92	1	1200
.05%	1	73	1	960
.06%	1	61	1	800
.07%	1	52	1	685
.08%	1	45	1	600
.09%	1	40	1	532
.10%	1	36	1	480

Soap. Any good soap may effectively be used as a contact insecticide. The best soap is that which is made with caustic potash rather than with caustic soda. Soda soap washes are apt to gelatinize when cold and are made difficult or impossible to be used as a spray. Fir tree oil soap may be used at the rate of three ounces to each five gallons of water without injury to plants. Whale oil soap should be used at the rate of only one-fourth pound to each gallon of water. A stronger solution may injure tender plants.

Sulphur. This is used not only as a fungicide, but also as an insecticide as well. When used as a fumigant, sulphur at the rate of one-third of a pound to each 1,000 cubic feet of greenhouse space will be effective. When ready to fumigate the house is closed tightly, the required amount of sulphur weighed out and divided into four equal parts on

clean paper. The sulphur is then placed in wide, deep metal pans at the bottoms of which are first placed chips which have been soaked in kerosene. The pans are solidly placed at equal distances on raised bricks in the center aisle of the house. When all is in readiness fire is set to the chips. When these begin to burn well the sulphur is spread evenly on the burning chips of each pan. As soon as the sulphur ignites, the operator should run out and shut the door of the house as quickly as possible. Sulphur fumes have an irritating and suffocating effect on man. The sulphur fumes should be allowed to act for at least twelve hours before one opens the house. The sulphur fumigation may be started at any convenient time during the day or night. This treatment will destroy red spider and mildew.

Hydrocyanic-Acid Gas. There seems no doubt that fumigation with hydrocyanic gas offers the cheapest and most efficient method of controlling white flies, aphids, thrips, scales, and mealy bugs. However, this method has not yet gained general popularity because of the deadly nature of the gas and its injury to plants when overdone. The best generators for the gas are one-half or one gallon glazed earthenware jars. When ordering generators it should be indicated that tops are not desired.

Before fumigating it is essential to see that all broken glass is repaired, and that all cracks are carefully stopped up. It is very essential that the cubical contents of the greenhouse be accurately determined. To secure the cubical contents of an even

span house compute the number of square feet in the rectangle and in the right angles, and multiply the sum of the three by the length of the house. To secure the cubical contents of a three-quarter span house multiply the sums of the areas of the rectangles, and the areas of the right angle triangles by the length of the house. In estimating the cubical contents of a greenhouse it is not necessary to make allowances for the space occupied by pots or benches. Fumigation should never be attempted during high winds. It should never be done during the day and not earlier than one hour after sunset. It is never wise to fumigate when the outside weather is near the freezing point. Nor is it well to fumigate during humid nights. The best time to fumigate is when the temperature ranges from 55 to 68 degrees F.

The chemicals required for fumigation are either sodium cyanid (NaCN) or potassium cyanid (KCN), sulphuric acid (H_2SO_4), and water (H_2O). Sodium cyanid is preferred. It should be free from chlorin and contain not less than 51 per cent of cyanogen. Cyanid is a violent poison. It should be stored in airtight cans and carefully labelled "*Violent Poison.*" Commercial sulphuric acid of 66 degrees Baumé or 1.84 specific gravity will answer the purpose. Upon referring to Tables 20 and 21 we see at a glance the amount of cyanid per each 1,000 cubic feet necessary to kill the particular insect and the amount each plant can stand. For example, if one-half ounce of cyanid as indicated in

Table 21 is used per 1,000 cubic feet of space, and if the greenhouse to be fumigated contains 15,000 cubic feet, then multiply the number of cubic feet contained in the greenhouse by the amount of cyanid to be used per 1,000 cubic feet, 1,500 times ½ equals 7.5 ounces cyanid. If there is the least doubt as to the amount of gas the plant can stand without injury the initial dose should not exceed one-fourth ounce for each 1,000 cubic feet of house space.

TABLE 20

Amounts of Cyanid and Number of Fumigations Sufficient to Destroy Various Greenhouse Pests

Insects	*Ounces per 1,000 Cubic Feet*	*Number of Fumigations Required*	*Interval Between Fumigations*
			Days
*Aphids	½	1	
Azalea lacewing	½	1	
Thrips	½	2	10
Greenhouse white fly	½	3	7 to 9
Long scale	¾	1	
**Greenhouse orthezia	¾	2	21 to 28
**Palm mealybug	2½	1	
Palm aphis	2½	1	
**Long-tailed mealybug	2½	2	do.
Florida red scale	2½	2	do.
Thread scale	2½	2	do.
Aspidistra scale	2½	2	do.
Soft brown scale	2½	2	do.
Hemispherical scale	2½	2	do.
Tessellated scale	2½	2	do.
Florida fern caterpillar	5	1	
†Citrus mealybug	5	2	do.

*For the most part aphids can be controlled with one-half ounce of sodium cyanid per 1,000 cubic feet, although there are a few species which are quite resistant to this gas and not so readily killed.

†The greenhouse Orthezia and mealybugs around the roots of plants are very difficult to kill, and this dosage is recommended only for those occurring above the soil.

TABLE 21°

Results of Fumigation with Hydrocyanic-acid Gas in Greenhouses and Boxes.

Name of Plant	Rates in Ounces per 1,000 Cubic Feet		Exposure in Hours	Greenhouse Temperature	Infestation	Results of Treatment	
	Sodium Cyanid	Potassium Cyanid				On Plants	On Insects
				F			
Abutilon sp.	½	.....	1	58	Greenhouse white fly	No burning	All stages except eggs and late pupæ killed
do.	¾	.....	1	68	do.	do.	do.
Acalypha sp.	¾	.....	1	60		do.	
Achyranthes sp.	¾	.....	1	60		do.	
Ageratum sp.	½	.....	1	58	Greenhouse white fly	do.	do.
do.	5	.....	1	52		Tender tips burned	
Air plant	¾	.....	1	68	Aphids	No burning	100% killed
Allamanda hendersoni	½	.....	1	60		do.	
Alpinia sanderæ	½	.....	1	62		do.	
Alternanthera sp.	½	.....	1	60		do.	
*do.		10	1	73		do.	
Althea sp.	½	.....	1	60	Aphids	do.	do.
Amaranthus sp.	¾	.....	1	55		do.	
Amaryllis sp.	¾	.....	1	68		do.	
Anthericum comosum	½	.....	1	60	Long scale	do.	80% killed
do.	¾	.....	1	60	do.	do.	100% killed
Anthurium sp.	½	.....	1	60		do.	
Ardissia sp.	½	.....	1	62		do.	
Araucaria excelsa	½	.....	1	66		do.	
Aristolochia sipho	.....	5	¾	66		do.	
Artemisia sp.	.....	1½	1	73		Slight burning	
Artillery plant	½	.....	1	70		No burning	
Asparagus plumosus	½	.....	1	66		Tips burned	

°Tables 20 and 21 from Sasscer, E. T. and Borden, A. D., U. S. Dept. of Agr. *Farmer's Bulletin 880:* 3–19, 1917.
* Plants fumigated in a box.

TABLE 21 (continued)

Name of Plant	Rates in Ounces per 1,000 Cubic Feet		Exposure in Hours	Greenhouse Temperature	Infestation	Results of Treatment	
	Sodium Cyanid	Potassium Cyanid				On Plants	On Insects
Asparagus sprengeri	½	.....	1	60	....	Tender tips burned	
Aspidistra lurida	2½	.....	1	62	Florida red scale	No burning	100 % killed
Aster	½	.....	1	62	....	do.	
Aucuba japonica	¾	.....	1	68	....	do.	
Azalea sp.	5	.....	1	50	Greenhouse thrips	do.	do.
do.	½	.....	1	60	do.	do.	do.
do.	½	.....	1	60	Azalea lacewing	do.	do.
do.	¾	.....	1	60	Azalea Eriococcus	do.	50% killed
do.	.....	7½	1	......	....	Slight burning	
Begonia sp.	½	.....	1	60	Greenhouse Orthezia	No burning	70% killed
do.	5	.....	1	52	....	do.	
Berberis rehderiana	½	.....	1	62	....	do.	
Bougainvillea	¾	.....	1	56	....	do.	
do.	5	.....	1	52	....	Foliage burned	
Buxus sp.		7½	1	......	....	No burning	
Calendula	½	.....	1	60	....	do.	
Caladium	5	.....	1	52	....	do.	
Camellia japonica	5	.....	1	52	Citrus mealy-bug	do.	100% killed
*do.	10	.....	1	60	....	New growth burned	
Canna	½	.....	1	64	....	No burning	
Carnation	1	.....	1	54	Greenhouse thrips	do.	do.
*do.	5	.....	1	73	....	Tender foliage burned	
Centaurea	½	.....	1	60	Onion thrips	No burning	95% killed
Cereus (night-blooming)	2½	.....	1	63	....	do.	
Chrysanthemums:							
Single-stem var.	½	.....	1	62	Aphids	do.	100% killed
do.	¾	.....	1	68	do.	do.	do.
Pompon var.	½	.....	1	62	do.	do.	do.
do.	1	.....	1	67	do.	do.	do.
Cigar plant	¾	.....	1	68	do.	do.	do.

* Plants fumigated in a box.

TABLE 21 (continued)

Name of Plant	Rates in Ounces per 1,000 Cubic Feet		Exposure in Hours	Green-house Temperature	Infestation	Results of Treatment	
	Sodium Cyanid	Potassium Cyanid				On Plants	On Insects
Cineraria	¾	.....	1	60	Aphids	No burning	100% killed
Clerodendron	.....	5	¾	66	.....	do.	do.
Cockscomb	⅓	.....	1	64	.....	do.	
Coleus	¾	.....	1	66	Greenhouse Orthezia	do.	do.
Columbine	5	.....	1	59	.....	do.	
Coreopsis	½	.....	1	62	.....	do.	
Cosmos	½	.....	1	60	.....	Tips burned	
Croton	¾	.....	1	56	Long scale	No burning	do.
do.	5	.....	1	52	Immature citrus mealy-bug	do.	do.
*do.	10	.....	¾	68	Long scale	do.	do.
Cycas circinalis	2½	.....	1	63	Florida red scale	do.	do.
Cyclamen	¾	.....	1	68	.....	do.	
*do.	10	.....	1	60	.....	Flowers killed	
Daffodil	¾	.....	1	55	.....	No burning	
Deutzia gracilis	.....	1⅛	½	.....	Aphids	do.	do.
Digitalis	⅓	.....	1	62	.....	do.	
Dioscorea pentaphylla	½	.....	1	64	.....	do.	
Dracæna knerki	2½	.....	1	63	Long-tailed mealy-bug	do.	do.
Dracæna indivisa	.....	5	¾	52	.....	do.	
Dusty miller	½	.....	1	60	.....	do.	
Erica sp.	½	.....	1	64	.....	do.	
Eupatorium sp.	¾	.....	1	60	.....	do.	
Euphorbia sp.	⅓	.....	1	60	.....	do.	
Euonymus sp.	⅓	.....	1	60	.....	do.	
Ferns:							
Adiantum cuneatum	5	.....	1	59	.....	do.	
do.	5	.....	¾	62	Larvæ of Fla. fern caterpillar	do.	do.
*do.	7½	.....	¾	68	do.	do.	do.
*do.	10	.....	¾	68	do.	New growth burned	do.

* Plants fumigated in a box.

TABLE 21 (continued)

Name of Plant	Rates in Ounces per 1,000 Cubic Feet		Exposure in Hours	Green-house Temperature	Infestation	Results of Treatment	
	Sodium Cyanid	Potassium Cyanid				On Plants	On Insects
Adiantum croweanum....	5	.....	1	59	....	No burning.......	
Adiantum gracilium......	½	.....	1	57	Fern aphid........	do.	100 % killed
Adiantum trapeziforme...	½	.....	1	57	do.	do.	do.
Adiantum cardiocheleana.	2½	.....	1	63	....	do.	
Aspidium tsus-sinense....	2½	.....	1	59	....	do.	
Asplenium nidus-avis....	¾	.....	1	68	....	do.	
Cyrtomium rochfordianum	2½	.....	1	59	....	do.	
Cyrtomium falcatum.....	¾	.....	1	60	....	do............	
Lastræa chrysoloba.....	¾	.....	1	68	....	do............	
Nephrolepis bostoniensis..	2½	.....	1	63	Aspidistra scale....	do............	do.
*do.	5	.....	¾	62	Larvæ of Fla. fern caterpillar.......	do.	do.
*do.	7½	.....	¾	68	do.	do.	do.
*do.	10	.....	1	68	do.	New growth burned	do.
*do.	.....	5	½	76	Aspidistra scale....	No burning.......	All stages except eggs killed
Nephrolepsis scottii......	2½	.....	1	59	....	do.	
Nephrolepsis whitmanii..	2½	.....	1	59	....	do.	
do.	5	.....	¾	66	Larvæ of Fla. fern caterpillar.......	do.	100% killed
Polystichum setosum.....	¾	.....	1	60	....	do.	
Pteris wilsoni...........	2½	.....	1	63	....	do.	
Pteris wimsetti..........	2½	.....	1	63	....	do.	
Ficus elastica...........	2½	.....	1	59	Florida red scale....	do.	do.
Ficus pandurata........	2½	.....	1	63	Long-tailed mealy-bug...........	do.	do.
Ficus utilis.............	2½	.....	1	63	....	do.	
Forget-me-not..........	½	.....	1	56	....	do.	
do.	5	.....	1	52	....	Tips burned......	
Forsythia viridissima.....	.....	1⅘	½	......	Aphids...........	No burning.......	do.
Fresia................	¾	.....	1	60	....	do.	

* Plants fumigated in a box.

TABLE 21 (continued)

Name of Plant	Rates in Ounces per 1,000 Cubic Feet		Exposure in Hours	Greenhouse Temperature	Infestation	Results of Treatment	
	Sodium Cyanid	Potassium Cyanid				On Plants	On Insects
Fuchia	½	.....	1	60	Aphids	No burning	100 % killed
Fuchia	½	.....	1	60	Greenhouse white fly	do.	All stages except eggs and late pupæ killed
do.	5	.....	1	58	.....	Tips burned	
Gaillarida sp.	½	.....	1	62	.....	No burning	
Gardenia	5	.....	1	60	.....	do.	
do.	7½	.....	1	......	.....	Slight burning	
Genista	¾	.....	1	55	Red spider	No burning	No killing.
do.	5	.....	1	52	do.	Flowers and new growth burned	100% killed
Geraniums:							
Bedding	½	.....	1	60	Greenhouse white fly	No burning	All stages except eggs and late pupæ killed
do.	5	.....	1	60	.....	New growth burned	
Peppermint	¾	.....	1	68	.....	No burning	
Rose	½	.....	1	64	.....	New growth burned	
Gladiolus	¾	.....	1	55	.....	No burning	.....
Heather (Scotch)	¾	.....	1	68	.....	do.	
do.	.....	5	¾	52	.....	Slight burning	
Heliotrope	¾	.....	1	60	.....	No burning	
do.	5	.....	1	58	.....	Tips burned	
Hibiscus sp.	¾	.....	1	55	.....	No burning	
Hyacinth (Roman)	2	.....	1	56	.....	do.	
Hyacinth (water)	¾	.....	1	55	.....	do.	
Hydrangea	¾	.....	1	60	.....	do.	
Impatiens sultani	¾	.....	1	68	Aphids	do.	100% killed
Ipomaœ grandiflora	¾	.....	1	60	.....	Open flowers burned	
Ivy (English)	5	.....	1	48	Fla. red scale	No burning	96% killed

TABLE 21 (continued)

Name of Plant	Rates in Ounces per 1,000 Cubic Feet		Exposure in Hours	Green-house Temperature	Infestation	Results of Treatment	
	Sodium Cyanid	Potassium Cyanid				On Plants	On Insects
Ivy (German)	¾	.....	1	58	Spanish red scale	No burning	100% killed
Iris (Spanish)	½	.....	1	64	.....	do.	
do.	.....	5	¾	66	.....	Tips burned	
Jerusalem cherry	½	.....	1	60	Aphids	No burning	do.
Lantana	½	.....	1	60	Orthezia	do.	90% killed
do.	¾	.....	1	56	.....	do.	
Laurus nobilis	5	.....	1	54	Soft brown scale	.....	95% killed
					Laurel scale	No burning	98% killed
					Long-tailed mealy-bug		100% killed
do.	.....	7½	1	.....	Soft brown scale	No burning	90% killed
Lilies:							
Calla	½	.....	1	64	.....	do.	
do.	.....	5	¾	65	.....	do.	
Lilium formosum	½	.....	1	60	Aphids	do.	100% killed
do.	¾	.....	.....	60	.....	do.	
Lilium multiflorum	½	.....	1	60	Aphids	do.	do.
do.	¾	.....	1	60	.....	do.	
Lilium speciosum rubrum	½	.....	1	58	Aphids	do.	No killing
Lobelia	5	.....	1	59	.....	Tips burned	
Marguerite	½	.....	1	70	Aphids	No burning	100% killed
do.	½	.....	1	60	Immature hemi-spherical scale	do.	95% killed
do.	¾	.....	1	68	.....	do.	
Marigold (French)	¾	.....	1	64	.....	do.	
Mignonette	½	.....	1	60	.....	do.	
do.	5	.....	1	52	.....	Tips burned	
Mimulus moschatus	¾	.....	1	56	.....	No burning	
Narcissus poeticus	¾	.....	1	55	.....	do.	
Narcissus barri	¾	.....	1	55	.....	No burning	
Nasturtium	¾	.....	1	55	.....	do.	

Table 21 (continued)

Name of Plant	Rates in Ounces per 1,000 Cubic Feet		Exposure in Hours	Greenhouse Temperature	Infestation	Results of Treatment	
	Sodium Cyanid	Potassium Cyanid				On Plants	On Insects
Nigella sp.	½	.....	1	62	Aphids	No burning	100% killed
Nymphæa sp.	2½	.....	1	63		do.	
Orchids:							
†Angræcum eburneum.	½	.....	1	60		do.	
*†do.	5	.....	1	62	Diaspis sp.	Slight burning	do.
†Brassea verrucosa	½	.....	1	57		No burning	
†Calanthe (hybrid)	½	.....	1	58		do.	
†Cattleya mossiæ	½	.....	1	60		do.	
†Cattleya trianæ	½	.....	1	57	Thrips	do.	All stages except eggs killed
‡Cattleya trianæ	20	.....	¾	70		do.	
‡Cattleya sp.	.....	20	½	......		do.	
do.	.....	21	1	......		do.	
do.	.....	42	½	......		Slight burning, plant recovered	
Chysis aurea	½	.....	1	57		No burning	
*Cœlia baueri	5	.....	1	62		do.	
Cœlogyne cristata	½	.....	1	57		Few old leaves burned	
*Cœlogyne flaccida	5	.....	1	62	Chaff scale	No burning	100% killed
Cœlogyne massangeana	½	.....	1	60		do.	
Cœlogyne speciosa	½	.....	1	57		do.	
Cymbidium pendulum	½	.....	1	57		do.	
Cypripedium callosum	½	.....	1	60	Thrips	do.	All stages except eggs killed
Cypripedium calypso	½	.....	1	60	do.	do.	do.
Cypripedium spicerianum.	½	.....	1	60	do.	do.	do.
Cypripedium venustum	½	.....	1	57	do.	do.	do.
*Cypripedium sp.	5	.....	1	62		do.	

* Plants fumigated in a box.
†Orchids in growing condition, practically all having new growth, flower bud, or blossom.
‡Imported orchids without new growth.

TABLE 21 (continued)

Name of Plant	Rates in Ounces per 1,000 Cubic Feet		Exposure in Hours	Green-house Temperature	Infestation	Results of Treatment	
	Sodium Cyanid	Potassium Cyanid				On Plants	On Insects
Dendrobium aggregatum	½		1	57		No burning	
Dendrobium ainsworthi	½		1	57		do.	
*Dendrobium fimbriatum	5		1	62	Lepidosaphes	do.	100% killed
Dendrobium grandiflorum	½		1	57		do.	
Dendrobium nobile	½		1	60		do.	
Dendrobium parishii	½		1	57		do.	
Epidendrum prismatocarpum	½		1	57		do.	
Lælia anceps	½		1	57		do.	
Lælia acuminata	½		1	57		do.	
Læli superbiens	½		1	60		do.	
Maxillaria graminifolia	½		1	57		do.	
Oncidium embratium	½		1	60		do.	
Oncidium papiliomajus	½		1	60		do.	
Oncidium sphacelatum	½		1	57		do.	
Oncidium splendidum	½		1	57		do.	
Odontoglossum sp	½		1	57		do.	
Phalænopsis schilleriana	½		1	60		do.	
Pholidota imbricata	½		1	57		do.	
Spiræa sp	¾		1	60		No burning	
Stephanotis floribunda		5	¾	60		do.	
Stevia	½		1	60		do.	
Stocks	½		1	62		do.	
Swainsona sp	½		1	60		do.	
Sweet peas	½		1	60	Aphids	Tips and blossoms burned	100% killed
Sweet-william	½		1	56		No burning	
Thunbergia erecta	½		1	64		do.	
Tulip	¾		1	55		do.	
Umbrella plant	2½		1	63	Red spider	do.	do.
Verbena (hardy)	¾		1	60		do.	

* Plants fumigated in a box.

TABLE 21 (continued)

Name of plant	Rates in Ounces per 1,000 Cubic Feet		Exposure in Hours	Green-house Temperature	Infestation	Results of Treatment	
	Sodium Cyanid	Potassium Cyanid				On Plants	On Insects
Verbena (lemon)........	½	.....	1	64	....	New growth burned	
Vinca major variegata...	¾	.....	1	56	....	No burning.......	
do.	.....	5	¾	56	....	do.	
Vinca rosea............	¾	.....	1	60	....	do.	
Violet..................	5	.....	1	48	Aphids...........	do.	100 % killed
Wandering Jew.........	½	.....	1	64	....	Severe burning....	

Mixing the Chemicals. The chemicals should be mixed as follows: For each ounce of sodium cyanid use 1½ fluid ounces of sulphuric acid and 2 fluid ounces of water. The water is first placed in the generators, then the sulphuric acid. The cyanid is then dropped into the warm acid, and the manipulator must at once leave the greenhouse and shut the door tightly behind him.

Short exposure with a greater strength of gas is more desirable than overnight exposure with a weaker gas. Better results are obtained when the fumigation lasts about two hours. After fumigation the house is opened at the top or at the side doors to allow the escape of the gas. During cold weather the ventilators should be opened for a short time only at several intervals.

It is not advisable to fumigate if the house temperature is below 52 degrees F. or above 70 degrees F. As already stated, fumigation should never be done while the sun shines. Hydrocyanic acid gas is soluble in water. It is, therefore, evident that neither the plants nor the benches should be wetted before fumigation.

Don'ts in Fumigation

The following don'ts laid down by Sasscer and Borden will be of value to the greenhouse man:

"Do not *guess* the amount of chemicals to be employed or the cubic contents of the house.

"Do not fumigate plants in a greenhouse in daylight.

"Do not fumigate when the temperature in the greenhouse is below 52 degrees or above 70 degrees F.

"Do not leave the chemicals within reach of those unacquainted with their poisonous nature. Always have them properly labeled.

"Do not handle the chemicals any more than is absolutely necessary. It is well to have a pair of old gloves for this, and to use them for no other purpose. Always wash the hands thoroughly after handling the chemicals whether gloves have been used or not.

"Do not allow the acid to splash or drop on the clothing or skin.

"Do not stay in the greenhouse any longer than is necessary to place the cyanid in the jars, and never enter a greenhouse charged with the gas until it has been thoroughly aired.

"Do not fail to post danger signs at all entrances before setting off the charge, and to see that the greenhouse is closed tightly.

"Do not attempt to fumigate a large greenhouse alone.

"Do not fumigate a greenhouse adjoining a dwelling without notifying the occupants before fumigation.

"Do not pour water on the acid; pour acid on the water.

"Do not become negligent in any of the precautions; to do so may cause serious results."

Emulsions

Kerosene Emulsion. The formula for kerosene emulsion is as follows:

Kerosene	2 gallons
Water	1 gallon
Hard soap	½ pound

Dissolve the soap in the water by heating. Remove the soapy water from the fire and add the kerosene and the liquid, violently mixing until a stable milky emulsion is formed. This emulsion should afterwards be mixed with water without the kerosene separating from it. As a spray for soft-bodied sucking insects, the above stock solution should be diluted ten to twenty times. Kerosene emulsion is not extensively used in greenhouses.

Linseed Oil Emulsion. Linseed oil emulsion has been recommended by Vinal* for red spider on greenhouse cucumbers. The emulsion according to Vinal is made as follows:

(a) *The necessary articles for preparation are:*

1. Bucket pump.

2. Container or mixing tank. This should hold at least eight or nine gallons. For this purpose a small washtub is perhaps the most available. Pails may be used, provided the materials are mixed proportionally.

3. Ivory soap.

4. Raw linseed oil.

5. Hot water.

* Vinal, S. C., Mass. Agr. Expt. Sta., Bul. 179: 175-176, 1917.

(b) *The following proportions of materials for 100 gallons of spray are used:*

1. Five gallons of hot water.

2. One and one-half pounds of Ivory soap. (Six 5-cent cakes or three 10-cent cakes.)

3. One gallon of raw linseed oil.

(c) *Steps in the preparation of stock solution follow:*

1. Put the required amount of hot water in the container.

2. Shave the Ivory soap into this and stir until completely dissolved.

3. If at this time the temperature of the soap solution is too hot for the hand to bear, dilute with one gallon of cold water and let it stand until about body temperature or lukewarm. The cooling of this solution is necessary in order to prepare a permanent emulsion; otherwise the oil will come to the surface on standing (see No. 6). It also prevents the chemical and physical killing properties of the linseed oil from being changed by heat.

4. Add slowly, while stirring vigorously, one gallon of linseed oil.

5. Completely emulsify by using the bucket pump and turning the stream back into the container again, keeping the nozzle below the surface of liquid. Five minutes' vigorous pumping should completely emulsify this solution.

6. Set aside for a few minutes while preparing spray tank in order to see that oil does not come to the surface.

(d) *The following are directions for the preparation of spray tanks and spray:*

1. Fill the 100-gallon spray tank about one-half full of water. If the water used is too cold, upon the addition of the stock solution the soap will solidify into small lumps, thus spoiling the emulsion. This may occur early in the spring, when the water is very cold, but later in the season ordinary top water may be used without danger of the soap solidifying on the addition of the stock solution.

2. Add stock solution made above. (See (c) 1, 2, 3, 4, 5, 6.)

3. Agitate. (If lumping occurs, the addition of a few pails of hot water will remedy this.)

4. Fill the 100-gallon spray tank.

Fungicides

These poisons are used to control fungous diseases. As previously stated, some parasitic fungi live on the surface of the leaves and stems and are therefore easily controlled. An example of this is the powdery mildew. Other fungi, and these are in the larger majority, are those which live parasitically within the tissue of the host, and therefore cannot be reached by any spray. Fungicides are helpful only in preventing entrance of the parasite in the host. They are as ineffective in controlling insect pests as are insecticides in controlling fungous diseases.

The author has often referred in this work to the term "standard fungicide." In reality there is no

one standard fungicide. The term as employed here, however, refers to any effective fungicide that is best adapted to each particular case. For instance, Bordeaux mixture may be termed "standard" if used to spray greenhouse muskmelons or cucumbers. In this case the staining of the Bordeaux would not injure the marketable product since the Bordeaux film may be readily washed or wiped off. However, Bordeaux mixture could not be termed standard for spraying roses in bloom. At that time the Bordeaux stain may injure the market value of the bloom more than would the disease that we wish to control. In this case, therefore, ammoniacal copper carbonate or some other colorless fungicide may be termed standard.

Bordeaux Mixtures. The strength used for tender plants is three pounds of copper sulphate—also known as blue stone, six pounds of lime, and fifty gallons of water. The easiest way to prepare it is to dissolve the blue stone thoroughly in twenty-five gallons of water. The best quality of unslaked lime should be used and slaked in a little water, care being taken, however, not to flood it while slaking, nor to let it become too dry. When the slaking is completed, enough water is added to make twenty-five gallons. The lime water and the blue stone solution are then mixed, pouring in first one part of lime water, then another part of the blue stone; the mixture is then strained and used at once.

For crops with less delicate foliage, the standard Bordeaux mixture is 4-4-50; that is, four pounds

copper sulphate, four pounds unslaked lime, and fifty gallons of water. With greenhouse crops it is not always necessary to prepare stock solutions. Only enough for immediate use is prepared at one time.

In preparing Bordeaux the following points should be kept in mind:

(1) Copper sulphate solutions must be kept only in vessels of wood, fiber, brass, bronze, or copper. They must not be kept in iron or tin vessels, as they corrode them.

(2) It is necessary to use fresh lime, as air-slaked lime is useless.

(3) Bordeaux mixture can be used only when freshly mixed. If allowed to stand twelve hours after making, it loses all fungicidal value.

(4) Bordeaux mixture or lime should never be strained through burlap. The lint of the burlap is likely to work up into the nozzles and clog them.

(5) Undiluted solutions of copper sulphate or lime should never be mixed together.

(6) Bordeaux mixture should not be prepared with hot water.

Ammoniacal Copper Carbonate. The objection to the use of Bordeaux is that it stains the leaves and foliage.

To avoid staining, colorless ammoniacal copper carbonate may take the place of Bordeaux. It is prepared as follows:

Copper carbonate	5 ounces
Ammonia (26° Baumé)	3 pints
Water	50 gallons

The best results are obtained when the copper carbonate is first made into a paste with a little water. It is then dissolved by adding the ammonia, which is diluted with four quarts of water. If three pints of ammonia fail to dissolve all the copper carbonate, more may be used. Ammoniacal copper carbonate is only effective when used fresh. It loses its fungicidal value by standing, as the ammonia evaporates quickly.

Sulphur. Flowers of sulphur are often used to control powdery mildew or asparagus rust. It may be applied either by hand or with a duster. There are a number of other fungicides on the market which are not mentioned here. They should be thoroughly tested before they are used.

Combination Sprays. For purposes of economy, it is advisable to control both insect pests and fungous diseases at the same time. Spraying, if properly done, is effective in controlling or in keeping in check all the pests which attack greenhouse crops. In combining a fungicide with an insecticide, we may accomplish two aims in one operation. The various spray mixtures which may or may not be combined are indicated by Cooley and Swingle *—

	Tobacco Extracts	*Bordeaux Mixture*
Paris green	yes	yes
Arsenate of lead	yes	yes
Arsenite of zinc (ortho)	yes	no
Arsenite of lime	yes	yes

* Cooley, B. A., and Swingle, D. B., Montana Agr. Expt. Sta. Circ. 17: 119-151, 1912.

Each of these preparations is mixed and applied just as if it were used alone. A combination of the ammoniacal copper carbonate with an arsenate would be unsafe, since the ammonia renders the arsenic more soluble, and hence may result in the burning of the foliage. However, it may be safely mixed with the tobacco products.

Recent investigations by Professor Safro, Entomologist to the Kentucky Tobacco Products Co., indicates that "Black Leaf 40" may be used without soap in combination with such spray chemicals as lime-sulphur, arsenate of lead, arsenite of zinc, and iron sulphate, for controlling sucking and chewing insects and fungous diseases. Professor Safro's work further claims that "Black Leaf 40" may be safely combined with Bordeaux, and the desired results obtained. He writes as follows: "For purposes of spraying, add to every one hundred gallons of Bordeaux three-fourths of a pint of 'Black Leaf 40.' As far as safety to the foliage is concerned, much greater strength of nicotine may be added to the Bordeaux, but no additional effectiveness will be given to the mixture as an insecticide. Any nicotine solution which contains four hundredths of one per cent nicotine will be effective in controlling plant lice if the spraying is thoroughly done."

PROPORTION OF COMBINED SPRAYS

Bordeaux and Paris Green

Paris green	½ pound
Bordeaux mixture	50 gallons

Bordeaux and Arsenite of Soda

Arsenite of soda	1 quart
Bordeaux mixture	50 gallons

Bordeaux mixture must never be combined with kerosene emulsion, carbolic acid emulsion, and miscible oils.

(d) *Potassium Sulphide.* Like sulphur, this is a valuable fungicide for the control of the powdery mildew. The following strength is recommended:

Potassium sulphide	4 ounces
Water	10 gallons

Potassium sulphide is effective only if used immediately after it is prepared. It loses its value by being exposed for any length of time.

Stickers. It is well known that with some plants, such as cabbage, spray mixtures cannot be made to stick. The use of an adhesive added to the spray mixture will largely overcome this difficulty. An adhesive may be prepared as follows:

Resin	2 pounds
Sal soda (crystals)	1 pound
Water	1 gallon

The resin and the sal soda should be added to one gallon of water and boiled in an iron kettle for one and a half hours until clear. For plants which are hard to wet, such as cabbage or onions, the amount of the solution given above should be used for each fifty gallons of Bordeaux or ammoniacal copper carbonate. For other plants, this amount is added to each one hundred gallons of the spray mixture.

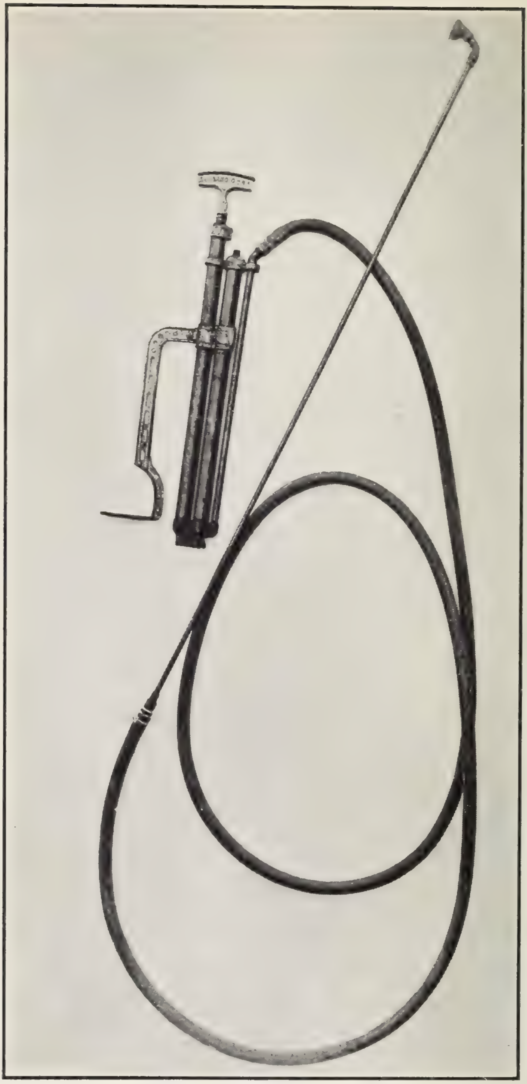

Fig. 81. Bucket Spray Pump with Long Nozzle.

Principles Involved in Spraying

It should be remembered that to destroy chewing insects, such as caterpillars, etc., the stomach poison must be evenly distributed all over the plant. This thorough spraying should be done as soon as the presence of the pest is suspected. Intelligent and observant growers will remember the time of appearance of the pest every year, although this date depends somewhat on the climate of each season. In destroying the green aphids, the contact poison should be distributed as evenly as possible on the insect itself. It is, therefore, best to spray for aphids when they are actually found working on the plants. To check chewing insects and fungous pests, however, the applications are made before the parasites appear. Before spraying it is necessary to have well in mind which organism is to be destroyed, and the proper ingredients to be used. To keep fungous pests in check it is necessary to have the plant covered with the fungicide all the time infection is feared or suspected. This spraying is preventive, protecting the plant from becoming infected. When the parasite has penetrated the host, spraying is of little value in saving the infected plant, although it will protect others which are as yet healthy. It is essential that the gardener be always ready to spray. Sometimes delay for even a day may prevent the attainment of positive results. The timely destruction of one insect, or of one spore,

means the elimination of countless generations of these pests.

Thoroughness is as important in spraying as it is in everything else in life. Especially is this true for the control of fungous diseases.

Spraying Machines

Success in spraying often depends on the sprayer, and especially on the nozzle. In small scale such as under greenhouse conditions, it is next to useless to invest in elaborate expensive machinery. A small bucket pump with long nozzle (fig. 81) as used by Professor Paddock of the Texas Experiment Station has given good satisfaction. The Auto Spray No. 1 is a very desirable spraying machine for indoor plants.

Hygienic Considerations

Since plants are endowed with life they readily respond to intelligent hygienic treatment. This is especially true with indoor plants, which at best are growing under abnormal conditions. Every effort should, therefore, be made to create indoors as nearly normal conditions as possible. The effect of proper sunlight, heat, moisture and ventilation has already been discussed under pages 53-85. Cleanliness is also an important consideration. The walks, interior walls and glass should be kept as clean as possible. Old and used pots should be scrubbed and washed at least once a year. Dead or infected plants should

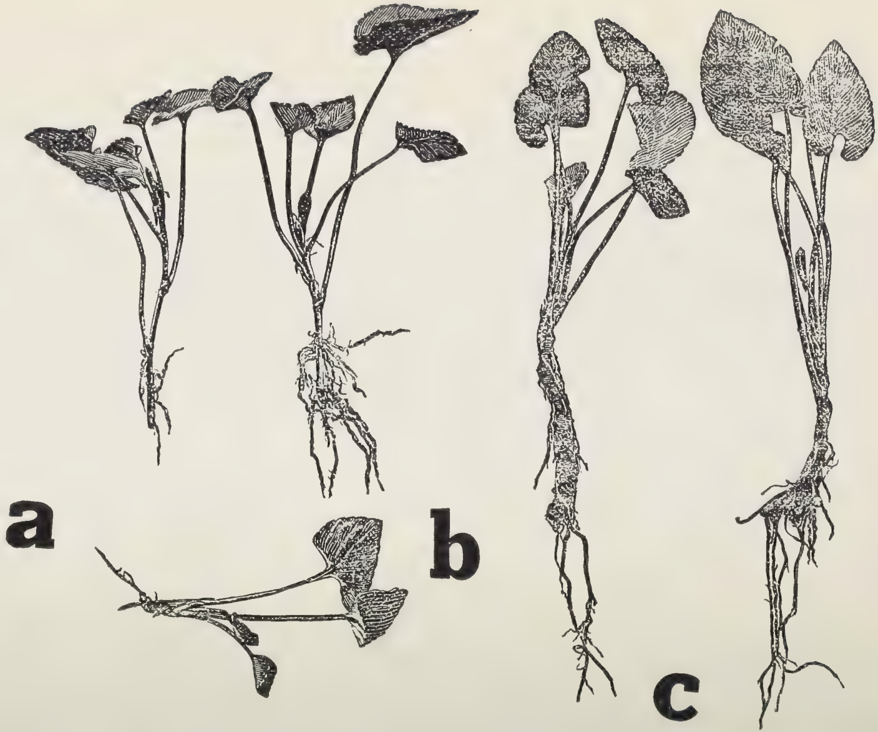

Fig. 82.

a. Ideal type of violet cuttings from mature wood, *b.* violet cuttings from old wood, *c.* violet cuttings from insufficient stem (after Galloway).

never find their way on the manure pile. Such manure is bound to find its way back and will contaminate the soil in benches and involve later extra expenses of soil sterilization. Insects and diseases should never be allowed to get a strong foothold. It is easy enough to destroy a few aphids for instance, but it becomes a matter of greater difficulty to handle a greenhouse which has become thoroughly infested. No definite rules can be laid down, but every greenhouse man must study his crops and his conditions in order to succeed in keeping his plants in the best condition of health.

Selection of Cuttings

With forced crops, perhaps more than with any others under glass, the success of cuttings is largely dependent upon proper selection. This is true for instance with carnations, roses, violets or chrysanthemums. It would scarcely seem possible that the nature of the cutting could materially influence the future plant. This, however, is a fact which has been aptly mentioned by Galloway.* It must be remembered that plants, like animals, are influenced by inheritance as well as by environment. In selecting cuttings the object should be to procure those parts of the plant which will transmit with the greatest vigor the ability to flower or to fruit as the case may be. Experienced growers will appreciate this. Frequently in starting with two-rooted cut-

* Galloway, B. T., Year Book, U. S. Dept. Agr., 247-256, 1895.

tings from the same plant, grown under the same conditions, dissimilar plants are produced. The one may be vigorous, blooming freely, while the other may be dwarfed and sickly, and produce no flowers, or merely a few of an undesirable type. In the selection of cuttings, appearance alone should not constitute the main guide. A cutting may appear vigorous, yet be immature or too old. Violet cuttings made from old wood will generally produce inferior plants, which will run out within a year or be carried off by disease. Violet cuttings made from soft, immature wood, will result in weak, spindly growth and in plants susceptible to damping off. On the other hand, a cutting may be made of the proper material, yet if it is too short it will also be useless. A violet cutting that is too short will not have sufficient anchorage. Each time a flower is pulled it will roll around or its roots will break (fig. 82, a to c.).

Not only is care necessary in the selection of cuttings, but it is also necessary to provide proper conditions for growth. A setback at this time may result in disappointing returns later. Heat, air, light and water should be carefully attended to in dealing with soft-wooded cuttings.

GLOSSARY

A

Acervulus (Acervuli). A non-sexual, open cup-shaped fruiting body of fungi.

Æcidiospores. Spores of rust fungi borne in an Æcidium.

Æcidium (Æcium). A cup-shaped body in which are formed the spring spores of certain rust fungi.

Aërobe. Micro-organisms requiring air, more especially oxygen.

Ammonification. The formation of ammonia at the expense of other forms of nitrogen compounds, accomplished through the action of soil micro-organisms upon organic substances.

Ammonifiers. Soil micro-organisms which are capable of transforming nitrogen compounds into ammonia.

Amœboid. Like an amœba, the creeping movement of which is made possible by appendage-like bodies.

Antheridium. The male sexual organ of fungi.

Apical. Terminal formation at the point of any fungous structure.

Ascospore. Spore borne in an ascus.

Ascus (Asci). Winter sexual spore sac, within which are formed the ascospores.

Arthrospores. Whole vegetative cells of either bacteria or fungi which, by a thickening of their walls, become resting spores.

B

Bacterium (bacteria). Simplest form of plant belonging to a low order, lacking chlorophyll, and reproducing by means of fission.

BASIDIOSPORES. Spores formed on basidia.

BASIDIUM (basidia). A straight stick-like spore bearing fungous thread.

C

CANKER. Definite dead area in the bark of stems or roots of plants.

CAPITATE. Possessing a head.

CARBONACEOUS. Dark to black colored.

CHLAMYDOSPORES. Resting spores of fungi possessing thick walls and formed within mycelial cells.

CHLOROPHYLL. Green coloring matter in leaves of higher plants.

CILIATE. Fringed with hair.

CILIUM (Cilia). Thread-like appendages on bacteria or zoospores of myxomycetes, which aid in their movement.

COLUMELLA. Sterile axle of a pillar-like structure within a sporangium.

CONIDIA (conidium). Spores formed asexually on free borne conidiophores.

CONIDIOPHORE. A spore bearing fungal stalk.

CUTICLE. The outermost skin of plants.

CYST. Incrusted body.

D

DELIQUESCENT. Dissolving or melting.

DIFFUSE. Loosely spread.

DILATED. Enlarged.

E

ENDOSPORE. Spore formed within another cell.

ENTOMOGENOUS. Fungi living parasitically on insects.

ENZYME. An organic chemical product capable of bringing about changes, but without itself undergoing any change or entering into the final product.

EXOSPORE. Outer covering of a spore.

F

Falcate. Sickle shaped.

Flagella. Whip-like appendage of bacteria or swarm spores.

Fungus (fungi). Plant of very low order with vegetative growth (mycelium), reproducing by means of sexual and non-sexual spores.

G

Glaucus. Sea green.

Gonidia. Algæ-like cells.

Guttulate. Drop-like.

H

Haustoria (haustorium). Special organs of fungi used for attachment or for obtaining food.

Host. Any plant which nourishes a parasite.

Hyaline. Translucent or colorless.

Hypertrophied. Any part of diseased plant abnormally enlarged.

Hypha (Hyphæ). Thread-like vegetative part of fungi.

I

Indurated. Hardened.

Infect. To cause disease.

Intercellular. Growing between the host cells.

Intracellular. Growing inside the host cells.

L

Lenticel. A special loose corky structure in plants intended to serve as a medium of exchange of gases.

Lesion. A definite diseased area.

M

MACROCONIDIA. Large conidia.

MICROCONIDIA. Very small conidia.

MIDDLE-LAMELLA. The connecting or cementing membrane between any two cells of a plant.

MYCELIUM. Vegetative threads or hyphæ of a fungus.

MYCOLOGY. The study of fungi.

O

OMNIVOROUS. Attacking a large variety of plants.

OOGONIUM. Female sexual organ of fungi containing one or more oospheres.

OOSPHERE. Naked mass of protoplasm developing into oospores after fertilization.

OOSPORE. Fertilized oosphere.

P

PAPILLATE. Possessing wing-like structure.

PARAPHYSES. Sterile filaments found in some fruiting forms of fungi.

PARASITE. An organism living at the expense of another (the host).

PATHOGENIC. Producing disease.

PEDICILLATE. Borne on a stalk.

PERITHECIUM. A flask-shaped or globose, sexual fruiting body containing asci.

PERITRICHIATE. Flagella formed all over the surface of an organism.

PIONNOTES. An effuse conidial stage, containing a maximum of conidia, and a minimum of aerial mycelium.

PLASMODIUM. A mass of naked protoplasm with numerous nuclei, capable of amœboid motion.

POLAR FLAGELLA. Flagella borne at the pole ends of a micro-organism.

PROTOPLASM. The living substance of any plant cell.

PSEUDO. False.

PUSTULE. A blister or pimple.

PYCINIDIA. Sack-shaped fruiting bodies of a fungus in which the pycniospores or summer spores are formed non-sexually.

PYCNIOSPORES. Non-sexual summer spores borne in pycnidia.

S

SAPROPHYTE. A micro-organism living on dead organic matter.

SCLEROTIUM (sclerotia). Compact mass of mycelium in a dormant state, living over from year to year.

SEPTUM. Any partition between two cells in the same fungous filament.

SETÆ. Bristle-shaped bodies of fungi.

SOIL FLORA. Bacterial or fungus growth of a soil.

SORUS. Heap of spores.

SPORANGIOPHORE. Stalk bearing sporangium.

SPORANGIOSPORES. Spores formed in a sporangium.

SPORANGIUM. Free, non-sexual bearing spore sack.

SPORE. A cell capable of reproducing a plant like its parent. It corresponds in function to the seeds of higher plants.

STOMATA. Minute openings in the stems, leaves or fruits of plants which serve as a medium of exchange of plant gases.

STROMA. A spore-bearing cushion composed of mycelium and sometimes of host tissue.

SWARM SPORES. Spores possessed with the power of motion, or motility.

T

TELEUTOSPORES (teliospores), resting or winter spores of rust fungi.

TELIUM. A sorus in which teleutospores are borne.

U

Uredospores. Summer spores of rust fungi.

V

Vesicular. Composed of vessels.
Viscid. Sticky.

Z

Zoogloeæ. Colony imbedded in a gelatinous bed.
Zoosporangia. Sporangia, which produce zoospores.
Zoospores. A motile spore.

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